This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

The following SCHOOLBOOKS, hitherto published by Mr JAMES GORDON, are now Published by OLIVER AND BOYD, Edinburgh; Simpkin, Marshall, and Co., London.

*** *A specimen copy of any Book will be sent* POST-FREE *on receipt of the retail price in postage stamps.*

EXHIBITION MEDAL.

A Prize Medal was awarded to Mr GORDON by the Jurors of the International Exhibition of 1862, "for the merit of his important Educational Works."

Poetical Reading Book.

With Aids for Grammatical Analysis, Paraphrase, and Criticism; and an Appendix on English Versification. By J. D. MORELL, A.M., LL.D., Author of Grammar of the English Language, etc., and W. IHNE, Ph. D. Second Edition. 2s. 6d. Containing—

THE DESERTED VILLAGE.
THE TASK (Book I.)
PARADISE LOST (Books I. & V.)
THE MERCHANT OF VENICE.
THE PRISONER OF CHILLON.
THE FIELD OF WATERLOO.
MISCELLANEOUS SELECTIONS.

School Geography.

By JAMES CLYDE, LL.D., one of the Classical Masters of the Edinburgh Academy. With special Chapters on Mathematical and Physical Geography, and Technological Appendix. Seventh Edition. 4s.

"We have been struck with the ability and value of this work, which is a great advance upon previous Geographic Manuals. . . . Almost for the first time, we have here met with a School Geography that is quite a readable book,—one that, being intended for advanced pupils, is well adapted to make them study the subject with a degree of interest they have never yet felt in it. . . . Students preparing for the recently-instituted University and Civil Service examinations will find this their best guide."—*Athenæum.*

Dr Clyde's Elementary Geography.

Eighth Edition. 1s. 6d.

*** In the *Elementary Geography* (intended for less advanced Pupils), it has been endeavoured to reproduce that life-like grouping of facts—geographical portraiture, as it may be called—which has been remarked with approbation in the *School Geography.*

Geography of the British Empire.

By WILLIAM LAWSON, Training College, Durham. 3s.

PART I. Outlines of Mathematical and Physical Geography.—II. Physical, Political, and Commercial Geography of the British Islands.—III. Physical, Political, and Commercial Geography of the British Colonies.

Bookkeeping **nd Counting-house**

By D ppendix on Commercial Forms.
By J my, and Church of Scotland
Traini 6d. KEY, 4s. Ruled Books,
2s. 6d.

J. 36.

MR GORDON'S BOOKS, now issued by OLIVER & BOYD.

Corkran's Concise History of England in Epochs.

With Maps and Genealogical and Chronological Tables. Fourth Edition. 2s. 6d.

*** A very full CHRONOLOGICAL TABLE has been added to this work, which forms also a TABLE OF CONTENTS.

English Composition for the Use of Schools.

By ROBERT ARMSTRONG, Madras College, St Andrews; and THOMAS ARMSTRONG, Heriot Foundation School, Edinburgh. Part I. Fourteenth Edition. 1s. 6d. Part II. Fifth Edition. 2s. Both Parts in one, 3s. KEY, 2s.

Armstrongs' English Etymology for the Use of Schools. 2s.

Armstrongs' English Etymology for Junior Classes. 4d.

English Composition in Prose and Verse,

Based on GRAMMATICAL SYNTHESIS. By W. SCOTT DALGLEISH, M.A., Vice-Principal of Grange House School, Edinburgh. Second Edition. 2s. 6d.—KEY, 2s. 6d.

"The treatise is evidently, for the purposes of elementary instruction, at once the most practical and the most scientific exposition that we have yet had."—*Professor Craik.*

"Full of clear explanation, well chosen examples, and serviceable hints and directions."—*Athenæum.*

"The most rational and useful looking book on the subject that we have seen."—*The Reader.*

Wordsworth's Excursion. Book I. The Wanderer.

With Notes to aid in Analysis and Paraphrasing. By Rev. H. G. ROBINSON, Canon of York, Principal of the Diocesan Training College, York. 8d.

School Songs.

By T. M. HUNTER, Director to the Association for the Revival of Sacred Music in Scotland. With Preface by JAMES CURRIE, M.A., Principal of the Church of Scotland Training College, Edinburgh, and Author of "The Elements of Musical Analysis," etc.

PART I.—SCHOOL SONGS FOR JUNIOR CLASSES, containing 60 Songs, principally set for two voices. 4d.

PART II.—SCHOOL SONGS FOR ADVANCED CLASSES, containing 44 Songs, principally set for three voices. 6d.

Hunter's Elements of Vocal Music on the Original Sol-fa SYSTEM. 6d.

School Psalmody.

Containing 58 pieces, arranged for three voices. 4d.

Object-Lesson Cards on the Vegetable Kingdom.

Set of Twenty in a Box. £1, 1s.

*** The objects themselves are affixed to the Cards on which the Lessons are printed, showing the uses of the objects.

[*Continued at end of Book.*

Now ready, New Edition, 66 *pages,* 6*d.*,

WITH EXERCISES ON THE PROPOSED DECIMAL COINAGE,

LESSONS IN ARITHMETIC for Junior Classes.

By James Trotter, of the Scottish Naval and Military Academy.

This book was *carefully revised,* and *enlarged* by the introduction of Simple Illustrations of the various rules, and of Practical Exercises, by the Author's son, Mr Trotter, of the Scottish Institute; and to the present edition Exercises on the proposed Decimal Coinage have been added.

Uniform therewith, 76 *pages,* 6*d., New Edition,*

Trotter's Arithmetic for Advanced Classes,

Being a Continuation of the above.

With Exercises on the proposed Decimal Coinage.

Each subject is accompanied by an example fully worked out and minutely explained. The Exercises are numerous and practical.

NEW AND CHEAPER EDITION.

THE ANALYSIS OF SENTENCES; with Applications to Parsing, Punctuation, and Composition. By the Rev. Robert Demaus, M.A., F.E.I.S., West End Academy, Aberdeen. Fc. 8vo. **Reduced to 3d.**

This Treatise is intended to serve as a Supplement or Appendix to Grammars in which the Analysis of Sentences is either entirely omitted, or treated in a cursory and unsatisfactory manner.

Edinburgh: Oliver and Boyd.
London: Simpkin, Marshall, and Co.

OUTLINES

OF

MATHEMATICAL AND PHYSICAL GEOGRAPHY.

BY

WILLIAM LAWSON,

TRAINING COLLEGE, DURHAM.

EDINBURGH:
OLIVER AND BOYD, TWEEDDALE COURT.
LONDON: SIMPKIN, MARSHALL, AND CO.
1864.

Price One Shilling and Threepence.

Now ready, *Revised Edition,* 348 pages, 12mo, 3s.

GEOGRAPHY OF THE BRITISH EMPIRE.

By William Lawson, Training College, Durham.

Part I. Mathematical and Physical Geography.—Part II. Physical, Political,
and Commercial Geography of the British Islands.—Part III. Physical,
Political, and Commercial Geography of the Colonies.

For Schools and Private Students.

Edinburgh: Oliver and Boyd. London: Simpkin, Marshall, and Co.

PRINTED BY OLIVER AND BOYD, EDINBURGH.

PREFACE.

This little text-book contains the First Part of the author's *Geography of the British Empire*, and is published in a separate form to meet the wishes of those teachers who, while not requiring the Geography of Great Britain and her Colonies, would be glad to have a cheap text-book of Mathematical and Physical Geography. The first four chapters give a brief outline of those parts of popular Astronomy which are more immediately connected with Geography, and form a fitting introduction to the subjects discussed in the succeeding chapters. The brief sketch of Geology contained in Chapter V. will be found useful as setting forth some of those general principles on which Physical Geography is based; while at the same time, if thoroughly learnt, it will enable the pupil to prosecute successfully the study of one of the most interesting of natural sciences. It is not necessary that anything should be said on the importance of Physical Geography. Every practical teacher knows that without it no thorough knowledge of other branches of the science can be attained; while an acquaintance with a few of its general principles will enable the student to grasp a multiplicity of details, which would otherwise be a heavy burden to the memory.

Durham, *April* 1864.

CONTENTS.

CHAP. PAGE

I. Form and Magnitude of the Earth.—Methods of Finding Latitude and Longitude, ... 3

II. Distance and Magnitude of the Moon—of the Sun.—Diurnal and Annual Motions of the Earth.—Aberration of Light, ... 9

III. The Seasons.—Different Lengths of Day and Night.—Equation of Time.—Fixed Stars, ... 16

IV. Motions and Phases of the Moon—Eclipses—Tides, . 22

V. The Crust of the Globe.—Aqueous Rocks.—Igneous Rocks.—Geological Systems, ... 28

VI. Post-Tertiary System.—Distribution of Land and Water.—Form and Elevation of Continents.—Depth of the Ocean.—Atlantic Basin, ... 37

VII. The Atmosphere—its Uses.—Winds.—Effect of the Distribution of Land.—Monsoons.—Variable Winds, . . 44

VIII. Rains. — Theory of Rains. — Distribution in Tropical Regions—in Temperate Regions.—Dew.—Snow, . . 51

IX. Oceanic Currents.—The Equatorial Current.—The Gulf Stream.—The Pacific Gulf Stream.—The Open Sea in the Arctic Ocean.—The Salts of the Ocean.—Trade Routes, ... 58

X. Climate.—Zones of Temperature.—Causes which Influence Climate.—Isothermal Lines.—General Remarks, . 67

XI. Vegetable Zones.—Distribution of Plants and Animals.—Origin of Existing Vegetation.—Acclimatisation.—Plants of Commercial Importance, ... 75

XII. The Distribution of Man.—Great Varieties of the Human Family.—Subdivisions of the Caucasian Type.—Conclusion, ... 84

OUTLINES OF MATHEMATICAL AND PHYSICAL GEOGRAPHY.

CHAPTER I.

FORM AND MAGNITUDE OF THE EARTH.—METHODS OF FINDING LATITUDE AND LONGITUDE.

THE earth is an immense ball, isolated in space.—We know that the earth is isolated in space, because travellers have gone round it. Ships have set out from different parts, and, continuing in the same general direction, have at length returned to the place from which they started. We know also that the shape of the world is round. The common argument drawn from the appearance presented by a ship, when leaving or approaching the shore, is as true as it is familiar. The shadow of the earth as seen in an eclipse shows, also, that the earth is a globe; and if additional proof be needed, it may be remarked that the visible horizon, or boundary of our vision, is always a circle, and this could not be the case if the earth were not a sphere. Nor do the various elevations and depressions upon the earth's surface interfere with the spherical shape of it considered as a whole. This will be evident when the magnitude of the earth is considered. It will be shown afterwards that the diameter of the earth, that is, the measure *through* it, is about 8000 miles; now, as the highest mountain does not rise six miles above the sea level, such an elevation bears no greater proportion to the whole globe than a grain of sand to a globe 12 inches in diameter.

The earth is, then, an immense globe or ball. An imaginary straight line passing through its centre, and terminating each way at the surface, is called its **Diameter**; the two points on the surface where the diameter terminates are called **Poles,**—one is called the north pole, and the other the south pole; and a circle drawn round the globe, at an equal distance from each pole, is called the **Equator.** A circle drawn right round the earth, either at the equator or passing through the poles, is called the **Circumference.** Every circle may be divided into 360 equal parts called degrees; the circumference of the earth therefore contains 360 degrees; and if we could determine the length of one of them, we could find out the circumference of the earth. This has been done, and it is found that the *average* length of one degree is 69$\frac{1}{10}$ miles. Measuring degrees is very difficult work, but the general principle may be easily explained.

The sky always appears to an observer like half a hollow sphere. The point directly over the observer's head is called the **Zenith**; the boundary of his vision, or the line where the earth and sky appear to meet, is called the **Horizon.** A line drawn through the zenith and terminating in opposite points on the horizon would be a semicircle, and would contain of course 180 degrees—usually written 180°; half the semicircle, or the part between the horizon and the zenith, will contain therefore 90°. Turning now once more to our globe, we mentioned that a circle drawn right round the globe through both poles would be the circumference, and that it would contain 360°. That portion of it between the equator and either pole would be a fourth of a circle, and would contain therefore 90°;—the same number as was contained in the arc between the zenith and the horizon. If our observer were stationed at the equator, on a clear evening, he would see three stars near his zenith. They are in the constellation of Orion, and may often be seen in this country in the south part of the sky. On casting his eye northwards, our observer would see the pole star —so familiar to us—just on the horizon. If now he were to journey towards the north, he would find that, owing to the convexity of the earth, the pole star would appear to rise gradually in the heavens, or increase in **altitude**, while the three stars in Orion's belt would appear to descend. And if it were possible for him to reach the north pole, he would find the pole star then in his zenith, and the three stars of Orion on the horizon, or, in other words, while he had travelled over 90° on the earth's surface, a certain star had appeared to rise 90° in height, while three others had descended the same number of degrees. From other observations with different stars he would find that the same principle held in every case. Putting, therefore, this important conclusion into a general form, we find that, *if we travel over any number of degrees on the earth's surface to the north or south, some stars will appear to rise and others to descend the same number of degrees.*

The distance travelled over can be accurately measured by a process called **Triangulation.** In the first place, a base line has to be computed. A piece of firm level ground is selected, and a straight line eight or ten miles in length is measured by means of rods of brass or iron. As metals expand by heat, various contrivances are used to protect the rods from changes of temperature, and in some cases they are covered with canvass tents. Base lines have been measured in different parts of the British Islands, but the one most frequently referred to is measured along the sandy shore of Loch Foyle. After the base line has been measured—and this is done with such accuracy that sometimes in a distance of several miles the error is not supposed to exceed the fraction of an inch —the next step is to fix upon some distant object which can be distinctly seen either by the eye or by means of a telescope. The angle which this object makes when viewed from each extremity of the base line is then determined by means of a theodolite, and a triangle is thus constructed, the remaining two sides of which can be easily calculated. Each of these sides may now form the base of another triangle, and in this way the whole country may be divided into a number of large triangles, and the length of a straight line passing through these triangles may be computed. By the means we have described a meridian has been measured extending from Shanklin Down, in the Isle of Wight, to Balta in the Shetland Islands. Suppose, then, we could, as was explained in the last paragraph, measure the number of degrees passed over in travelling from the north to the south of Britain, and by means of triangulation could reduce this distance to miles, we might in this manner obtain the length of a degree. This has been done, not only in the British Islands, but in South Africa, in India, Russia, France, Lapland, Peru, and other places; and the average length of a degree is found to be $69\frac{1}{10}$ English miles. We say the average length, because as we approach the poles it is found that the degrees gradually lengthen; and from this circumstance it is concluded that the earth is not a perfect sphere, but is slightly flattened at the poles: the consequence of this being that the polar diameter is about 26 miles shorter than the diameter at the equator. As the length of a degree is about $69\frac{1}{10}$ miles, the circumference of the earth is about 24,876 miles, and its diameter 7912 miles nearly.

Latitude.—The position of any place upon the surface of the earth may be at once determined when its latitude and longitude are known. The former gives its distance, north or south, from the equator; the latter, its distance east or west of a certain point fixed upon;—in England the point agreed upon is Greenwich. The latitude of a place may be determined by observing the stars. It was mentioned in a preceding paragraph that an observer stationed at the equator would see certain stars in his zenith; and that as he proceeded towards the north—and we may add towards the south—these stars would appear to descend gradually. Now, if at any time he could find the distance of these stars from the zenith, in degrees, this would give him his distance in degrees north or south of the equator,—in other words his latitude. It will be evident that the same result might be obtained by finding the distance of the pole star above the horizon. Sometimes latitude is found by observing the altitude of the sun: for at certain periods of the year it shines directly upon the equator, and then the method of proceeding is precisely the same as with the stars. At other times, however, as we know, the sun is north or south of the equator, and then its **declination**, or distance north or south of the celestial equator—an imaginary line in the sky corresponding to the equator of the earth—must be taken into account. On the twenty-first of June, the sun is 23½° north of the equator; and on the twenty-first of December, as far south of it; therefore the distance of the sun from our zenith, if taken at either of these periods, would not give our distance from the equator, but our distance from the *tropic of Cancer*, in June; and from the *tropic of Capricorn*, in December: and to get our true latitude we should have to add 23½° in the first case, and deduct it in the second. The declination of the sun for every day in the year can be calculated beforehand, and is published in the *Nautical Almanac;* so that, if an observer at any place, on any day, could take the altitude of the sun, and then, by means of the tables referred to, make the necessary correction, he would at once determine the latitude of the place where he then was.

Longitude.—If we know the difference of *time* between any two places we know the difference in their longitude. The time of any place is regulated by the sun. When the sun is at its highest point in the sky, or, as it is termed, on the meridian, then it is mid-day: and as the sun rises in the east and moves completely round the earth in 24 hours, it is mid-day successively to every spot on the earth's circumference in that time. Places situated to the east will have mid-day sooner than those to the west; and if we knew the distance any place was to the east of another, we could tell how much sooner it would have sunrise, noon, and sunset. As we have before mentioned, the circumference of the earth may be divided into 360°, and as the sun moves round the entire circle in 24 hours, it will move over 15° in an hour, or one degree in four minutes. Suppose, then, a ship set out on a voyage carrying with it a marine chronometer set to Greenwich time. If in the course of a month or two it was observed that, when the sun was on the meridian, the chronometer only pointed to eleven, it would be at once concluded that the place where the observation was taken was an hour before Greenwich time, and therefore 15° farther east. If the chronometer pointed to two o'clock, it would be equally certain that the place was 30° west of Greenwich.

Of course, every thing depends upon the accuracy of the chronometers, and therefore every precaution is taken in their construction, so as to provide for variations which might be caused by changes in temperature and shocks received by the vessel. Still they cannot be made quite perfect, and therefore another and more usual way is to notice the exact time of the eclipses of the sun and moon, or the occultation of stars, or especially the eclipses of Jupiter's satellites. Some one or other of these phenomena takes place daily, and the exact time when they occur is calculated for years beforehand, and marked down in the *Nautical Almanac*, in Greenwich time. If, then, an observer finds that the eclipse, or occultation, takes place—say twenty minutes past seven, instead of seven, the time given in the almanac,—he at once concludes that he is five degrees east of Greenwich.

The lines of latitude are sometimes called **Parallels**, because they consist of circles drawn parallel to the equator, and of course these circles diminish as they approach the poles. The lines of longitude are called **Meridians**, because all places through which they pass have mid-day (*meridies*) at the same time. These meridians consist of semicircles of equal length passing from pole to pole; and one is fixed upon from which the others are measured east and west. In England, as has been before stated, the meridian of Greenwich is the one fixed upon; on the Continent each country generally reckons from the one passing through its capital. As the meridians all terminate in the poles, the degrees of longitude diminish as they approach the poles, while the degrees of latitude are everywhere of almost equal length (vide p. 6). The latitude and longitude of most places upon the earth's surface have been calculated, and maps of the world and of different parts of it, have thus been constructed. In those made according to *Mercator's projection*, the parallels and meridians are drawn as straight lines, instead of being curved; but these are rather *charts* than maps: it is not intended that the distribution of land should be accurately represented, but only currents of the air and ocean, and other facts connected with physical geography.

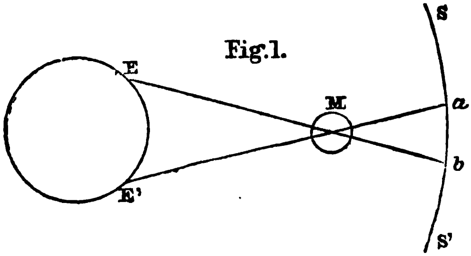
CHAPTER II.

DISTANCE AND MAGNITUDE OF THE MOON—OF THE SUN.—DIURNAL AND ANNUAL MOTIONS OF THE EARTH.—ABERRATION OF LIGHT.

It will be necessary here to say a few words about parallax. **Parallax** may be defined as the apparent change in the position of a heavenly body caused by a real change in the position of the observer. Let E—E′ represent a portion of the surface of the earth; M, the moon; and the curved line S—S′, a portion of the sky. If the moon be observed from E, it will appear to be among the stars at *b*; if from E′, it will appear to be at *a*. The arc *a*, *b*, or the angle *a*, M, *b*, represents the amount of parallax. Now, as this angle is the same as the angle

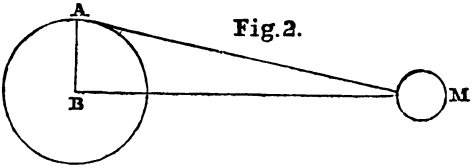
E M E′, we may change the form of our definition, and describe parallax as the angle made by two lines of vision formed by viewing a heavenly body from two different positions. **Horizontal parallax** is the angle formed by two lines of vision, one proceeding from an observer viewing the object when it is upon the horizon, and the other from an observer supposed to be at the centre of the earth. In finding the parallax of the moon, observations are generally taken at the same time at the Cape of Good Hope, and at Greenwich, or some other observatory in Europe. After some necessary corrections have been made, the *horizontal parallax* is calculated, and this is found to be about 57 minutes and 2 seconds, and from this the distance and magnitude of the moon can be determined. In order to explain this we must first speak of the unit of circular measure.

Fig. 1.



In an angle of 60°, as is well known, the chord of the arc is equal in length to the radius; but in an angle of little more than 57°, the arc itself is equal to the radius, and this particular angle is called the **Unit of Circular Measure.** If the angle be diminished, of course, the arc will be diminished also, but the radius always remains the same. Let us apply these facts to the horizontal parallax of the moon. Let M be the moon; A, the position of an observer when the moon is on the horizon; B, the centre of the earth. A, M, B, may be looked upon as part of an immense circle of which M A, M B, are the radii, and A B the arc; for, in an angle so small as is the horizontal parallax of the moon, the straight line

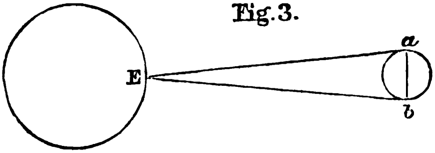
Fig. 2.



A B may be considered an arc, without materially affecting the calculation. The horizontal parallax of the moon is, as we have said, 57′ 2″; that is, about one-sixtieth part of the unit of circular measure; therefore, since the arc diminishes with the angle while the radius remains the same, the arc A B must be one-sixtieth of the radius A M. But the arc A B is the radius of the earth, which we have seen before (p. 6) is about 4000 miles; the distance of the moon, then, must be 60 multiplied by 4000, that is, 240,000 miles.

By a similar process the magnitude of the moon may be calculated when its distance is known. In figure 3,

Fig. 3.



let E be any point on the earth's surface; and *a-b*, the apparent diameter of the moon. On careful measurement it is found that the apparent diameter of the moon is about half a degree, that is, about a one-hundred-and-twentieth part of the unit of circular measure. The arc *a b*, therefore will be about a one-hundred-and-twentieth part of the radius *a* E. But *a-b* is the diameter of the moon; and *a* E is its distance from the earth; therefore the diameter of the moon is about a one-hundred-and-twentieth part of the moon's distance from the earth, and as this distance is about 240,000 miles, we conclude that the diameter of the moon is about 2000 miles. And since the magnitudes of spheres are to each other as the cubes of their diameters, it follows that the earth is 64 times the size of the moon.

The horizontal parallax of the sun may be determined in the same manner as that of the moon, but as the angle is very small the slightest inaccuracy affects the calculation considerably: other and more refined methods must therefore be adopted. It would be out of place for us to enter here upon these methods and calculations, and therefore we shall merely state that the parallax of the sun has been found to be about 8·6 seconds. The horizontal parallax of the moon is thus about 400 times larger than that of the sun, and therefore we conclude that the sun is 400 times farther from us. And since at this great distance the apparent diameter of the sun is about equal to that of the moon, it must in reality be 400 times greater. The diameter of the moon we have seen is about 2000 miles; the diameter of the sun must therefore be about 800,000 miles; that is, 100 times greater than that of the earth. The magnitude of the sun must therefore be one million times that of the earth. It may be added that none of the fixed stars have the slightest horizontal parallax, and therefore their distance must be much greater than that of the sun even.

We have hitherto spoken of the sun as if it moved round the earth once in 24 hours; let us, however, reflect upon this. The sun, it appears, is about 400 times farther distant from us than the moon is,—that is, about 95 million miles. If, then, the sun moves round the earth, it must every day describe a circle 600,000,000 miles in circumference: What, then, must be the velocity with which it moves? And what must be the velocity of the stars, which are still further distant? Such a supposition, then, is exceedingly improbable, and we may add, according to the laws of gravitation, impossible. We must, therefore, account for the apparent daily motion of the sun and stars in some other way, and we find that the phenomena would be exactly the same, if the sun and stars were stationary, and the earth turned round once every day upon its own axis. It is true we do not feel this motion, because it is so smooth and uniform, but there are, as we shall see hereafter, certain effects produced upon winds and oceanic currents which cannot be explained unless we suppose the earth to have a diurnal motion. But, indeed, this motion has been placed beyond a doubt by an ingenious experiment with the pendulum; however, to understand this would require a considerable knowledge of mathematics, and therefore a more familiar proof may be given.

It has been observed that if a stone be dropped from the top of a very high tower, it does not fall close to the base, but a little to the east of it: and this is the explanation given. The earth, in turning on its axis from west to east, carries the tower along with it: but as the top of the tower describes a larger circle than the bottom of it, it must move a little quicker. The stone which is dropped partakes of the motion of the top of the tower, and therefore, when it reaches the ground, as it was moving towards the east rather quicker than the base was, it falls a little in advance of it. This experiment has been performed in a most satisfactory manner, and is a convincing proof of the earth's daily rotation.

It appears, then, that the apparent daily motion of the sun and stars from east to west is due to the diurnal motion of the earth upon its own axis from west to east. From the time that the sun appears upon the meridian, until he comes upon the same meridian again, is 24 hours. But if we notice the stars carefully we shall find that they come to the same meridian again in 23 hours, 56 minutes. It would appear, then, as if the earth really took only 23 hours, 56 minutes, to turn once upon its axis, but that in the meantime the sun had moved a little to the east, and it took the earth 4 minutes more to bring the proper meridian under it. This fact was noticed by the ancients; they observed that the sun appeared to step a little to the east every day, and thus change his place among the stars,—for every one will have noticed that the same stars do not appear every evening—and that in a year the sun came round to its original position. They gave the name of **Degree** to the distance moved eastward by the sun each day; and as the year then consisted of 360 days, we can see how it happened that all circles came to be divided into 360 degrees. But does the sun move at all? Its daily motion from east to west is only *apparent:* May not this annual motion be merely apparent also? Now, it may be shown that the appearance presented by the sun moving among the stars would be the same whether we suppose the earth to be stationary and the sun to move round it, or the sun to be stationary and the earth to move round the sun. Certainly, the second supposition is the more probable one, when we consider the relative sizes of these two bodies: and this *probability* amounts to *certainty* when we consider the **Aberration of light.**

Let S be a star in the zenith, and A B the tube of a telescope. Light, we know, travels with great velocity,

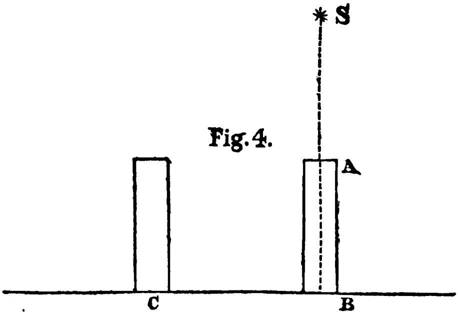


Fig. 4.

since it comes from the sun to the earth in eight minutes. Yet, rapid as the motion is, it will require some time—

though an exceedingly minute quantity—to pass down the tube of the telescope from A to B. If now the earth were at rest, the telescope would be so too, and it would not matter how long the ray of light was in passing from A to B, we should see the star in looking through the tube. If, however, while the ray was passing from A to B, the tube was moved to C, by the motion of the earth, the light would strike against the side of the tube, and the star would be invisible; and in order that we might see the star, the tube would have to be inclined a little.

Thus, in figure 5, we will suppose the tube inclined in the direction A B. Then, if while the ray of light was passing from A to C, the telescope was moved on from B to C, the ray would reach the eye of the spectator at C. And as an object always appears in the direction in which the ray of light appears to come, the star, instead of appearing to be in its true position S, would appear to be at S′, a little in advance of its true position. If, then, the earth has an annual motion, stars when viewed through a telescope will not appear in their real positions, but a little in advance of them; and as this will be the case from whatever part of the earth's path round the sun they are viewed, it follows that stars in the zenith will appear to describe minute circles round their real positions, the

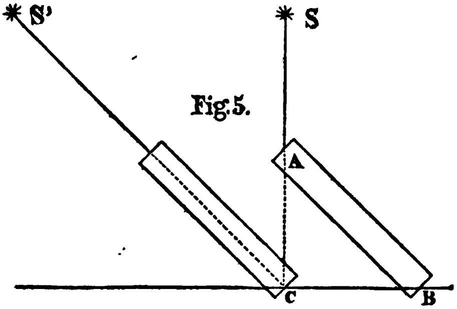


Fig. 5.

radius of these circles being the space between their real and their apparent positions. Now, such is really the case. Bradley, the astronomer, when endeavouring to find out the annual parallax of certain stars, found that they were not *fixed* as he before imagined, but that they revolved in very minute circles. This phenomenon, which he termed the *aberration of light*, he soon convinced himself was owing to the annual motion of the earth; and the existence of this motion, therefore, may be looked upon as settled.

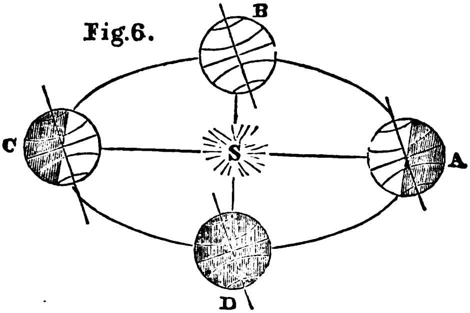
CHAPTER III.

THE SEASONS.—DIFFERENT LENGTHS OF DAY AND NIGHT. —EQUATION OF TIME.—FIXED STARS.

The earth, then, has two motions;—one, a diurnal motion round its own axis; and the other, an annual motion round the sun. The imaginary path which the earth takes in moving round the sun is called its **Orbit**; and the space included is called the **Plane** of the earth's orbit. The path traced out in the sky by the sun's apparent annual motion is called the **Ecliptic**: this does not coincide with the celestial equator (vide p. 7), for sometimes it is 23½° north, and at other times 23½° south of it. The reason of this is, that, in moving round the sun, the axis of the earth is not perpendicular to the plane of its orbit, but makes with it an angle of 66½°. This inclination of the earth's axis is the cause of the seasons.

In the accompanying figure, let S represent the sun, and A, B, C, D, the earth in four different positions in its orbit: the four straight lines are the prolongation of the earth's axis, and are always parallel. When the earth is at A, the upper or north pole is inclined to the sun, and the sun's rays strike perpendicularly upon the tropic of Cancer,—an imaginary line drawn round the earth 23½° north of the equator. At C, the vertical rays of the sun strike upon the tropic of Capricorn,—an imaginary line *south* of the equator corresponding to the tropic of Cancer. In the other two positions neither pole is inclined, and the sun is then perpendicular over the equator. When the sun is at A, it is summer in the northern hemisphere: at B, it is autumn: C, is its position in the middle of winter; and D, its position in spring. We may now explain how it is that the lengths of night and day vary with the seasons.

Fig.6.



If we hold a globe up before a candle we see that only one-half of it can be illuminated at the same time. It is so with the earth, only one-half of it can be lighted up at the same time by the rays of the sun; the other half is in darkness. The line which separates the light part from the dark part is called the **Circle of illumination.** When the earth was in the position A (figure 6), the sun shone directly over the tropic of Cancer: this point, therefore, must be the centre of the illuminated half, and the circle of illumination would stretch 23½ degrees on the other side of the north pole, but would not reach the south pole. As the earth turned upon its axis, all parts of its surface that came within the circle of illumination would have day; all beyond it, night; and it will be seen that so long as the earth remained in this part of its orbit, a space round the north pole within the *arctic circle*—an imaginary circle drawn round the earth 23½° distant from the north pole—would have continual day, while a space round the south pole, within the *antarctic* circle, would have continual night. At C the reverse of this would take place; the north pole would be shrouded in darkness, while the south pole would have one long day. When the earth is at B, or D, then, since the sun shines at these periods directly over the equator, the circle of illumination will pass through the poles, and days and nights will be of equal length, and the same for all parts of the world. These two positions in the earth's orbit are hence called **Equinoxes,**—a word meaning equal nights. As both the equator and the circle of illumination are *great* circles, that is, each of them divides the surface of the earth into two equal portions; and as great circles always bisect each other, the circle of illumination must always bisect the equator, and days and nights at the equator are therefore equal throughout the year: it is for this reason that the equator is sometimes termed the **Equinoctial line.** As we recede, however, from the equator, the days and nights become of unequal length, until at the pole there are "days and nights for half a year." We have before remarked, that during our summer, the sun, when on the meridian, appears each day to approach nearer and nearer to the zenith until he attains a certain altitude; for awhile he appears stationary, and then descends lower and lower each day until about the 21st December, when he has reached his lowest altitude, and, after being again stationary for awhile, again turns northward. The two periods when he appears stationary are called **Solstices,** a word meaning the standing of the sun; and the imaginary circles drawn through the extreme points reached by the sun in summer and winter respectively, are called **Tropics,** from a Greek word signifying *to turn* (see p. 16).

Between the summer solstice—when the earth is in the position A—and the autumnal equinox, and so on until winter, the days shorten and the nights lengthen in all parts of the northern hemisphere; but between the winter solstice (position C) and the vernal equinox, and so on to mid-summer, the days lengthen. When we consider this, and recollect at the same time, that in summer the rays of the sun are more vertical than in winter, owing to its greater altitude, we have no difficulty in accounting for the much higher temperature felt during summer than during winter. But curious as it may appear, the sun is actually nearer to us in winter than in summer. The earth's orbit is not a perfect circle, but an ellipse, and in winter it is about three million miles nearer the sun than in summer. But as the distance between the earth and the sun lessens, the velocity of the earth moving in its orbit increases, and thus the interval between the autumnal and vernal equinoxes is about eight days shorter than that between the vernal and autumnal equinoxes, and this compensates for the earth's nearer approach to the sun: for Sir John Herschel shows that during the former and shorter interval, the earth receives exactly the same amount of heat from the sun as it does in the latter and longer interval—(vide *Astronomy*, p. 198).

Equation of Time.—We have already mentioned (page 13) that the time required for any star which is upon the meridian to come again to the meridian, is four minutes less than 24 hours—the time required by the sun; the former interval is called a *sidereal* day, the latter a *solar* day, and in the ordinary business of life we make use of solar time. But solar days are not all of equal length: for as the difference between a sidereal day and a solar day is owing to the earth's annual motion, and as this motion is not always uniform but sometimes quicker than at other times, it follows that the solar days will vary in length; and we should expect them to be rather more than 24 hours from the autumnal to the vernal equinox, and rather less from the vernal to the autumnal equinox. But there is also another cause at work which disturbs the length of the solar day—the sun's apparent motion in the ecliptic. The ecliptic, it has been before observed, does not coincide with the celestial equator, but is inclined to it at an angle of 23½° (p. 16). If, therefore, the earth's motion in its orbit were uniform, the effect of the obliquity of the sun's apparent path would be to cause a difference in the lengths of solar days. For at the solstices the ecliptic is parallel with the equator, while at the equinoxes it is very oblique. We can see, therefore, that as the sun moves along the ecliptic about a degree every day, the space moved towards the east, as measured on the *equinoctial*, or celestial equator, would be greater at the solstices than at the equinoxes. Hence this cause alone would produce some irregularity in solar time, and the two causes combined make the solar day to vary about 50 seconds. Now, as it is very desirable that in the ordinary business of life, our days should be of uniform length, we take the average length of a solar day for our purpose: this is a *mean solar* day, and of course is 24 hours long. The difference in the length of solar days never exceeds 51 seconds, but as the excess or deficiency continues to accumulate for several days, there is sometimes as much as 16 minutes, 18 seconds difference between noon as marked by the sun's passage across the meridian, and the proper noon of *mean solar* time. This difference is called the *equation* of time; it is calculated beforehand for every day in the year, and is often published in common almanacs. In order to make use of the table, we should notice the exact amount of equation given for any particular day, and also, whether the sun is before the mean time or after it: then, having noted the exact time on the sun-dial, should take out our watch and put it the exact time before or after the sun, as the case may be.

It will be evident that we have hitherto only spoken of *local* time, for other places will have noon at a different time from us, just as they are to the east or west of us (vide p. 7). Astronomers, however, sometimes find it convenient to have some fixed instant, to reckon time from, common to all the world. This is done by reference to the motion of the sun or moon among the stars: time so reckoned is called *equinoctial* time.

Fixed Stars.—It was mentioned before (page 16) that Bradley discovered the aberration of light when endeavouring to find out the annual parallax of certain stars; it may perhaps be as well to say a few more words on this subject. We have already seen that it is difficult to determine accurately the horizontal parallax of the sun, as the angle is exceedingly small; and that it is impossible to detect any horizontal parallax of the fixed stars owing to their immense distance. It was next tried to find out an **Annual parallax,** by observing a star from two opposite parts of the earth's orbit, and thus the arc of the angle would be 190 millions of miles, instead of 4000 as in the former case. In the southern hemisphere there is a bright star in the constellation of the Centaur, the annual parallax of which is about two seconds: adopting the same means of calculation as was used in finding the distance of the moon (page 10), we find that this star must be 200,000 times further distant than the sun; and, so far as we have yet learned, this is the nearest to us of all the fixed stars.

Now, it has been calculated that the sun at the distance of this star would only shine with one-half of the star's brilliancy; hence it is probable that the star is itself a sun, and much larger than the centre of our system. The parallax of about eight other stars has been discovered, and the distance and probable size of each computed in a similar manner; and one of these, Sirius—the Dog-star—is supposed to be at least sixty times the size of the sun. Each of the stars visible to the naked eye, and many more which can only be seen through a telescope, is probably the centre of a system of planets, just as the sun is the centre of the solar system. This opinion is strengthened by the fact that some stars exhibit variable light at regular invervals; for this phenomenon can only be accounted for in two ways,—either these stars turn round on their own axes and have a bright and a dark side, or they have large opaque bodies revolving round them, which at regular intervals partially eclipse them.

In some cases it has been discovered that two or even three stars revolve round each other, though at immense distances apart; and it is now generally admitted that our sun itself revolves round some centre as yet unknown, its velocity being about 154,000,000 miles in a year. From this rate it has been calculated that the immense orbit in which it moves is about five million times wider than that of the earth.

CHAPTER IV.

MOTIONS AND PHASES OF THE MOON.—ECLIPSES.—TIDES.

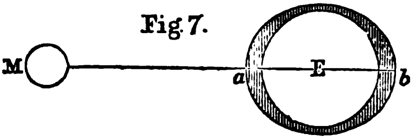
The moon moves round the earth just as the earth does round the sun; this journey it performs in 27 days, 7 hours, 43 minutes, and 11½ seconds, and as the face presented to the earth is always the same, we conclude that it turns once upon its own axis during the same interval. As the brightness of the moon is only the reflected light of the sun, and since the sun can only enlighten one-half the surface of the moon at the same time, it follows that the moon will present different appearances to us, as its position in its orbit changes. When on the opposite side of the earth to the sun, that is, when it comes on the meridian at midnight, then the whole of the illuminated side is turned towards the earth, and we have what is called *full moon*. When the earth, moon, and sun are in conjunction,—that is, when the moon is on the same side of the earth as the sun is, and therefore rises and sets with it,—then the dark side is turned to the earth, and therefore it is invisible: it is then *new* moon. Midway between new and full moon, or full and new moon, we see half the illuminated side, and then the moon is said to be in her quarters. Between new moon and her first quarter, the moon is **Crescent**; between full moon and her quarters, the moon is **Gibbous**. The word *crescent* means increasing; *gibbous* means hunchbacked. The different appearances which the moon presents in different parts of its orbit are termed **Phases**, from a Greek word, signifying appearance.

The moon, we have said, completes a revolution round the earth in little more than 27 days; this interval is called a sidereal month. A *lunar* month, that is to say, the interval between new moon and new moon again, is a little longer than this, being 29 days, 12 hours, 44 minutes, 3 seconds. The reason is this:—while the moon has been going round the earth, the earth has moved some distance forward in its own orbit, and consequently it takes rather more than two days for the moon to move on, in order to come again in a line with the earth and the sun, as it is in new moon.

Eclipses.—When the moon comes directly between the earth and the sun so as to intercept its light, then there is an eclipse of the sun: and when the earth comes between the sun and the moon so as to prevent the rays of light from reaching the moon, then there is an eclipse of the moon. The dark shadow which appears on the sun's disc during a solar eclipse is the shadow of the moon, and the dark shadow upon the moon's disc during a lunar eclipse is the earth's shadow: and as this shadow, or at least so much of it as is seen, is always circular, this affords one among other proofs that the earth is round (vide p. 3). From what has just been said, we might naturally expect that there would be two eclipses every month; one at new moon and the other at full moon. This would be the case if the *plane* of the moon's orbit coincided with the plane of the earth's orbit, for then at full moon and at new moon, the sun, the earth, and the moon would be in one straight line: but the plane of the moon is *inclined* to the plane of the earth at an angle of 5°, and hence at full and new moon the moon is sometimes above and sometimes below the sun. The question next arises—How is it, then, that there are ever any eclipses at all? In order to answer this question, we must say a little about the moon's *nodes.* The plane of the moon's orbit, we have said, is inclined to that of the earth's, at an angle of about 5°. The two points where the orbit of the moon cuts the plane of the earth's orbit are called **Nodes** (Latin *nodus*, a knot): these nodes are not stationary, but move about, and sometimes one of the nodes may come between the earth and the sun; and, of course, when that is the case the moon in going round its orbit will come between the earth and the sun, and just as it sometimes comes directly between the two, and sometimes only partially so, so there is sometimes a total eclipse of the sun, and sometimes only a partial one. The same remarks, of course, apply to the other node, and to the eclipse of the moon.

Tides are due principally to the attraction of the moon. The attraction of gravitation is a property of all matter; and as the earth attracts the moon and keeps it in its orbit, so the moon attracts the earth; and one result of this attraction is the formation of tides. Let E be the earth and M the moon; and, for the sake of clearness, let

Fig. 7.



us first suppose the earth to be entirely surrounded with water *a b.* Then the moon (M), in exerting its attractive power, will draw the water at *a* more than the earth itself: for the particles of water move over each other easily, while the earth, being a solid mass, must move all at once. Thus, on the side next the moon, the waters at *a* will be heaped up, and a tide will be formed. And as each place on the surface of the earth is brought successively under the influence of the moon in 24 hours, we might expect that there would be one tide each day everywhere. But there are *two* tides each day: the reason of this we will briefly explain. Referring again to our diagram, we see that the moon attracts the water at *a* more than the earth (E) itself; but it also attracts the earth more than the water at *b*, because the centre of the earth is nearer to it. Hence, the earth is drawn away from *b*, and the water, being left behind, appears bulged up on that side. Thus we see there are two tides always formed at the same time, on opposite sides of the earth; and thus it is, that every place has two tides in 24 hours.

The moon is the principal agent in forming the tides; for although the absolute attraction of the sun is greater, yet the difference of its attraction for different parts, as *a* and E, for example, is not so marked as in the case of the moon, and it is upon this difference that the height of the tides depends. When the sun and moon are in conjunction, as at new moon, or in opposition, as at full moon, then the tides are greatest, and are called **Spring tides.** For, if the sun and moon are on the *same* side of the earth, they both pull the same way, and their attractive power is united; if they are on opposite sides of the earth, they pull two opposite ways, yet still they assist each other, for each contributes its share in forming both the tides. When, however, the moon is in her quarters, and exerts her influence in a line at right angles to the direction of the sun's attraction, then the two forces counteract each other, and the tides are low: these tides are called **Neap tides.**

If the earth were covered by an ocean of uniform depth, the crests of the tidal wave would travel round it every day in regular succession, following the course of the moon from east to west. But it is only where there is a very great expanse of water that a real tidal wave can be formed; and as the largest expanse upon the globe is in the South Pacific Ocean, many scientific persons think that there alone is there a real tidal wave, and that the tides felt in other parts of the world are merely *derived* waves, similar in character to the ripple in a stream caused by throwing in a stone.

The Tidal Wave.—Suppose, then, a tidal wave is formed in the South Pacific, an impulse will then be given to the mass of waters around. In 12 hours this impulse is felt at Van Diemen's Land; in 12 hours more the high crest of wave stretches across the Indian Ocean, one extremity reaches Hindostan, the other is not far from the Cape. An interval of 12 hours more brings one extremity of the wave to Newfoundland, the other to Cape Blanco, on the west coast of Africa. Bending now to the east, the wave crosses the Atlantic, and in four hours reaches the mouth of the English Channel. Here the wave divides, one branch creeps slowly up the English Channel, another proceeds northwards, rounds the north of Scotland, and in eight hours reaches Aberdeen. It now proceeds slowly to the south, bringing high water successively to different ports on the east coast of Great Britain, and in twelve hours more reaches the mouth of the Thames. The wave that proceeded up the Channel travels very slowly, on account of the shallowness of the water, and only reaches the mouth of the Thames after an interval of eight hours; it then proceeds to the north, and in the neighbourhood of the Wash meets the other branch. A third branch from the Atlantic wave proceeds up St George's Channel and the Irish Sea, and in six hours reaches the Solway Frith. A glance at the map of Great Britain will show that on the east coast, from Duncansbay Head to the Wash, the inlets for the most part open to the north-east; while, on other parts of the coast, with one or two exceptions, which may be accounted for, the inlets are turned to the south. This may be owing to the fact that the tidal wave proceeds south from the Pentland Frith to the Wash, but on the other parts of the coast advances northward. Professor Airy, while admitting that the tides round the British coasts are derived waves, doubts whether the oscillations commenced in the South Pacific would be felt so far away from their source, and thinks it more likely that the disturbance originates in some part of the Atlantic basin.

The exact time at which high water occurs at any port, after new or full moon, is called the *establishment* of the port, and when this is once known, the time of high water, on any other day, may be calculated. For the tides follow each other regularly, with intervals of 12 hours and 25 minutes between. On a preceding page it was said that there are two tides in 24 hours; strictly speaking, we should say in 24 hours, 50 minutes. If the moon were stationary, the earth, having turned once round, would present the same meridian to it again in 24 hours; but in the meantime the moon has travelled 12 or 13 degrees onwards in its orbit, and the earth must turn a little more to the east to bring the moon upon the meridian; and the time required to do this is 50 minutes. On the south coast of England, Poole Harbour exhibits the curious phenomenon of two tides in 12 hours. The tidal wave flows regularly for 6 hours, it then ebbs for 1½ hours; it then flows again for 1½ hours, and ebbs during the remaining three hours. The second flow seems to be owing to the peculiar position of the entrance to the harbour. Being turned towards the east, it receives the waters of the ebb tide coming from between the mainland and the Isle of Wight. This causes a flow within the basin until the water outside is below the level of that within, when it again begins to ebb, and continues to do so until low water. A similar occurrence often takes place in the Frith of Forth, near Clackmannan, and is known to seamen as the "leaky tides."

The tidal wave moves quickest in deep water; in narrow shallow channels the wave travels slowly, and the waters accumulate; in the Bristol Channel and the Bay of Fundy, the tide has been known to rise 70 feet: and in the Bay of St Malo, on the north coast of France, it sometimes reaches 50 feet. Often at the mouths of rivers the tidal wave forms what is called the **Bore.** This is caused when either the shallowness of the water or the narrowness of the channel causes the first portion of the tidal wave to move so slowly that the succeeding waters accumulate perpendicularly. The bore in the river Hooghly at Calcutta is five feet high, that at the mouth of the Severn, nine; and at the mouth of the Amazon, 12 feet. There is a graphic account of the "eagre," or bore of the Tsien-Tang river, in China, given in a note to Maury's Physical Geography of the Sea, sec. 916.

CHAPTER V.

THE CRUST OF THE GLOBE.—AQUEOUS ROCKS.—IGNEOUS ROCKS.—GEOLOGICAL SYSTEMS.

The crust of the globe, so far as is known at present, consists of various kinds of rocks. In some places portions of hard rock have been ground small into sand; portions of softer rocks, mixed with organic remains, have assumed the form of soil: and very often different kinds of minerals and metals are met with. But all the different kinds of rocks, including all the different appearances under which they are found, may be grouped into two classes;—**stratified** and **unstratified** rocks. In the former class, the rocks consist of regular layers or *strata*, which sometimes, as in slates and flagstones, may be easily separated; in the other class, no marks of stratification appear. From carefully examining the nature of these two classes, geologists have concluded that rocks of the former class have been formed by the agency of water, and they, therefore, have termed them **aqueous** rocks: while those of the other class they suppose to have been formed by the action of fire, and they have, therefore, termed them **igneous** rocks.

In the stratified rocks, the remains of plants and animals are often found in a **fossil** state, that is, hardened into stone; and from a careful examination of these fossils, geologists have been enabled to classify the various aqueous rocks, and to determine which are of the oldest formation and which the most recent. The fossils found embedded in the rocks prove that the rocks themselves were at one time in a soft and yielding state, like sand or mud: and as the rocks composing a single system are very often several thousand feet in thickness, and as it would require an immense number of years to harden the soft mud or sand into rocks, we must conclude that many thousands, perhaps millions, of years have elapsed between the formation of the earliest and most recent systems. We may also remark that the plants and animals found in a fossil state are quite distinct from any now in existence; and therefore it would appear that the world had been created, and had been clothed with plants and inhabited by animals, long before the creation of man.

We may perhaps think that the teaching of geology contradicts the Mosaic account of the creation. But as God is the Author, both of nature and revelation, we may be certain that if our deductions from science are correct, they will not militate against Scripture. At one time it was thought that the discoveries of astronomy were contradicted by Scripture, but this opinion is no longer held. Men are beginning to see that as the Bible reveals to us truths which it would have been impossible for man otherwise to have known, so science presents problems which man, by the proper use of his reason, *may* discover: thus science and revelation have distinct provinces which ought not to be confounded together. Judging, then, from the facts presented by discoveries in geology, the first and most common opinion was, that there have been successive creations, as indicated by the different fossil plants and animals found in different systems of rocks; and that as it was only in the last creation that man appeared, so the Mosaic account referred to that creation alone. For a time this opinion was very generally received, but subsequent discoveries in this science have shown that there is no evidence of *breaks* between different systems; and that, therefore, the idea of successive creations divided from each other by a chaos cannot be considered tenable. The most probable theory is that set forth by the late Hugh Miller, in his *Testimony of the Rocks*, to the effect that there has been but one creation;—the one mentioned in Genesis; but that each day really means an immense duration of time. The chief difficulty in the adoption of this theory lies in the meaning of the word *day;* but it will occur to every one that in many parts of Scripture the word "day" means a larger portion of time than 24 hours.

We may suppose, then, that the world existed many thousands of years before the creation of man; but that during all these long periods it was being prepared for his abode, and when at last everything was in readiness then man was created. Each system of rocks represents, as it were, an epoch of time; and by carefully noticing the fossils of each system, along with the character of the rocks among which they are embedded, we may form some idea of the condition of the globe at the time these rocks were being formed. From a collection of the results thus carefully obtained, we find that originally the earth was in a fluid state, and had a much higher temperature than at present, and that from that period up to the creation of man, it went on cooling, and gradually became solid.

On examining the fossils of each system of rocks, we find that in the oldest formations animal and vegetable life was either altogether wanting, or only appeared in the lowest forms, but that gradually as the earth assumed its present temperature, and the distribution of land and water became as it is now, higher orders of plants and animals appeared. Sea-weeds, mosses, ferns, pines, tropical vegetation, and the trees and plants of temperate regions successively appeared; while in the animal kingdom, fishes, birds, and land-animals successively prepared the way for man. But it is in its relation to *Physical Geography* that we must at present treat of Geology, and its importance in this respect will be seen at once, when it is understood that upon the character of the rocks found in any district, not only the character of the minerals associated with these rocks, but also the general configuration of surface, and the variety of scenery, depend.

We have hitherto spoken only of *aqueous* rocks; but as these must have been formed at the bottom of rivers, lakes, and seas, and as the effect of aqueous agency is always to wear down, had there been no other contrary agency at work, the surface of the globe would gradually have assumed a smooth and monotonous level. But from the earliest periods there has always been an upheaving energy at work, and this agency is yet seen in volcanic eruptions, earthquakes, and boiling springs. What this agency is, and what is the origin of the force we cannot tell: probably there is some centre of heat in the interior of the earth to which all volcanic upheavals and irruptions of the present and former periods owe their origin. The *effect* of this upheaving force, however, is seen in the varied surface of the globe; hill, dale, mountain, and precipice—nay, the very existence of dry land above the surface of the water may be ascribed to it.

It is agreed amongst geologists, as a settled truth, that all stratified rocks were originally deposited in a horizontal position, and that therefore, whenever they appear out of this position, it must be owing to volcanic agency, and we may be sure to find igneous rocks in the neighbourhood. These rocks were originally in a hot fluid state resembling lava, and this molten matter having been forced up from the interior of the earth, in some cases caused simply an upheaval; in others, high mountain masses were formed, and sometimes the igneous matter has burst out, and appears on the surface. And it will be seen that, just in proportion as this igneous agency has been more or less active, so the rocks will be more or less displaced, and the surface more or less varied.

These eruptions and upheavals have occurred at every period in the earth's history, and therefore we find igneous rocks more or less associated with every geological system; but, as a general rule, the upheaving force has been more active in the earlier systems than in the later ones, and hence, as a general rule in those districts where the earlier systems of stratified rocks prevail—as in the Highlands of Scotland, for example—there we find the boldest and grandest scenery. In some cases the igneous matter coming in contact with stratified rocks has entirely changed their character: thus limestone has been crystallized into marble, and coal changed into coke.

As igneous rocks have been formed at different times, they differ in character and texture: but we may include them all in two great classes—**Granitic** and **Trappean.** Rocks of the former class—and granite may be taken as a specimen—occur generally in the earlier systems. The trappean rocks include *trap* and *basalt*. Trap derives its name from the Swedish word *trappa* a stair, and is so termed because of the terraced, or step-like, appearance of many hills where this rock is found. Basalt is a close-grained, dark-coloured rock, and often occurs in columns, more or less regular, of which fine examples may be seen in Fingal's Cave in the island of Staffa, and in the Giant's Causeway on the north coast of Ireland.

We shall now give a brief account of the different systems of stratified rocks, beginning with those of the oldest formation.

1. **Metamorphic System.**—The rocks belonging to this system are hard and crystalline, showing that they have been exposed to great heat. They are also destitute of fossils, and hence it is supposed that as yet neither animal nor vegetable life had any existence on the globe. Slate, marble, and granite are obtained from among the strata; and the ores of tin, copper, lead, silver, and gold are often found. The scenery in metamorphic districts is generally bold, rugged, and picturesque, but the soil is often sterile and unproductive.

2. **Silurian System.**—Among the rocks of this system we find roofing slate and flagstones, with ores of mercury, gold, and silver. The richest gold-fields in the world belong to this system. The fossils are all of a marine character, and consist chiefly of shell-fish; traces of mosses

and sea-weeds have also been found. The scenery is less bold than in metamorphic districts, but is perhaps more beautiful, being varied with hill, dale, ravine, and glen.

3. **Old Red Sandstone, or Devonian System.**—This system is composed chiefly of sandstone rocks, and they owe their reddish colour to the presence of iron in the water in which they were deposited. The distinctive fossils in this system are fishes of various forms, but all covered with hard enamelled scales, or bony plates. Among plants we find sea-weeds, rushes, and tree-ferns. Ripple-marks and impressions made by showers of rain are also occasionally found on the rocks. The minerals belonging to this system are not very important, consisting principally of flagstones and building stones. The scenery is often flat and tame, showing that igneous action has not been so great as in the two preceding systems; sometimes, however, "the hills of old red districts present great diversity of scenery; here rising in rounded heights, there sinking in easy undulations, now swelling into sunny slopes, and anon retiring in winding glens, or rounded valley-basins of great beauty and fertility." The soil is generally well adapted for agriculture.

4. **Carboniferous System.**—This is one of the most important of all the geological systems. Its rocks consist of sandstones, clays, shales, and limestones; and its fossils give evidence of an extraordinary abundance of vegetation. It is to the gigantic pines, palms, tree-ferns, reeds, and club-mosses which flourished at this period that we owe our extensive coal-fields. These plants all indicate a moist and equable climate; and as the fossils are of a similar character wherever coal-beds are found, it would appear that at this period all parts of the globe enjoyed a similar climate. This circumstance may be in great measure explained by supposing a different distribution of land from what now exists. The minerals belonging to this system are very valuable, consisting of building-stone, limestone, marble, lead, and silver; but, above all, iron and coal. In some places, however, as in Ireland, the

mountain limestone belonging to this system may be largely developed, while the *coal-measures* are almost entirely wanting. The scenery, with the exception of some limestone districts, is generally tame and unpicturesque; and the soil is often cold and only moderately fertile.

5. **Permian System.**—The principal rocks belonging to this system are sandstones, and yellowish magnesian limestones. The fossils are similar to those of the last system, but are by no means so abundant. There are traces also of true land-animals allied to the frog and lizard families. The minerals consist of excellent building-stones, limestones, gypsum, and copper. The scenery is generally tame and flat, and the soil affords rich verdant pastures.

6. **Triassic System.**—The rocks of this system are very similar to those of the last, and indeed the two systems are sometimes classed together as the *New Red Sandstone.* But it has been found that, in the Permian, the fossils are akin to those of the coal-measures and mountain limestone, while in the Triassic the plants are allied to the succeeding system. On slabs of sandstone belonging to the Triassic system well-defined footprints have been discovered. Some of these belong to a kind of lizard; but others appear to be those of a gigantic bird allied to the ostrich. The minerals are similar to those of the Permian system, if we substitute rock-salt for copper; and, like the Permian also, the soil is better suited for pastures than for mixed husbandry.

7. **Oolitic System.**—This system is mainly composed of limestones, sandstones, grits, shales, and clays, which indicate coral-reefs, sandbanks, beeches, and mud brought down by rivers and deposited in shallow seas. The distinctive fossils are those of huge reptiles belonging to the lizard family. Besides these there are traces of marsupial animals allied to the opossum and kangaroo, and the remains of an insectivorous creature have been detected. In some places fossil plants are very abundant, including coniferæ, allied to the yew and cypress, and abundance of leaves belonging to plants resembling the lily, pine-apple,

and aloe. The minerals are of considerable importance, including building, paving, and tilestones, marbles, alum, jet (a hard variety of coal), and fuller's earth. The scenery is, upon the whole, varied and pleasing, and the soil dry and fertile.

8. **Cretaceous System.** — This system is composed chiefly of sands, dark clays, and thick beds of chalk. The fossils are principally of marine origin, comprising sponges, corals, fishes, and reptiles; and there are remains of certain mammals supposed by Professor Owen to be those of monkeys. Fossil plants are comparatively rare. The minerals are chiefly chalk and flint, and occasionally fuller's earth, and an inferior kind of building-stone. The physical aspect of chalk districts is readily distinguished by the rounded outlines of the hills and valleys, as seen in the "Downs" of Kent and Sussex. These downs afford excellent sheep pasture.

9. **Tertiary System.**—About the beginning of the present century stratified rocks were divided into *Primary*, *Transition*, *Secondary*, and *Tertiary*. The *primary* rocks coincided with what are now called *metamorphic*, the *transition* answered to the *Silurian*, while the *secondary* embraced all the strata from the old red sandstone to the chalk. These terms have, in a great measure, given place to others of more accurate signification, though they are still occasionally met with. The tertiary division, indeed, even now retains its place, but it has been subdivided into four groups—the *eocene*, *miocene*, *pliocene*, and *pleistocene*, the last mentioned is also sometimes known as the "Drift." In their mineral composition these groups consist of clays, sands, marls, grits, and limestones. Leaving out for the present the "Drift," we may mention that among the fossil plants of the tertiary system, we meet for the first time with true exogenous trees, such as oaks, elms, and beeches; while among animals we have species of every existing order except man. It is during this period also that we first meet with traces of that geographical distribution of animals which now exists; thus the fossil animals

of South America are akin to its present sloths, ant-eaters, and armadilloes; while in Australia we meet with animals allied to its marsupials. Europe was at this time distinguished by its gigantic pachyderms, including elephants and rhinoceroses; and, judging from these and similar fossils, it has been concluded that the latitudes of England, France, and Central Europe enjoyed at this time a tropical climate.

The pleistocene group is almost destitute of fossils, and is remarkable for its water-worn blocks or *boulders*, which, with their smoothed and scratched surfaces, give evidence of the action of glaciers, icebergs, and arctic currents. "After the deposition of the lower tertiaries, it would seem that the latitude of Britain and the north of Europe underwent a vast revolution as to climate, and that some new arrangement of sea and land took place at the same period. At all events, the large mammalia of the earlier tertiaries disappeared, and the land was submerged to the extent of several thousand feet, for we now find water-worn boulders on the tops of our highest hills. A cold period ensued, and icebergs, laden with boulders and gravel from other regions, passed over these latitudes and dropped their boulders on our then submerged lands. How long this process continued, it is impossible to determine; but by-and-by a gradual elevation of the submerged lands took place, our hill tops and ranges appeared as islands, and our valleys as friths and straits. . . . . . In process of time the land was elevated to its present level, another distribution of sea and land took place, and the glacial epoch passed away. A new flora and fauna suitable to those new conditions were then established in Europe, and these, with the exception of a few that have since become extinct, are the species which now adorn our forests and people our fields."—(*Page: Text-Book of Geology.*)

The minerals belonging to the tertiary system include building-stone, marbles of various qualities, pipe and potter's clay, gypsum, and amber. The scenery in England is generally tame, but on the Continent the tertiary districts are often varied and picturesque. The soil is generally fertile.

CHAPTER VI.

POST-TERTIARY SYSTEM.—DISTRIBUTION OF LAND AND WATER.—FORM AND ELEVATION OF CONTINENTS.—DEPTH OF THE OCEAN.—ATLANTIC BASIN.

All the accumulations and deposits which have been formed since the close of the "Drift" are included by geologists under the term **Post-Tertiary.** These accumulations embrace peat-mosses, coral-reefs, sandbanks, gravel beaches, and alluvial deposits, and are more numerous and of greater extent than might at first be supposed. For the agencies which formed the various systems of stratified rocks are still at work,—rains, winds, and frosts still wear down the surface of the land; rivers carry down mud to form deltas and beaches, or to silt up seas and lakes; the ocean is constantly changing the outline of its shores, while the igneous agency, as seen in earthquakes, volcanoes, and boiling springs, is still exerting its upheaving force. The Hoang-ho, flowing through the alluvial plains of China, is said to carry down to the sea 2,000,000 cubic feet of solid mud every hour; the quantity carried down by the Mississippi is said to be still greater; and the Ganges is said to convey daily into the Bay of Bengal as much solid substance as is contained in the greatest pyramid of Egypt. We have said that the ocean is constantly changing the outline of its shores. There are numerous instances to prove this. The site of Ravenspur, once an important place in Yorkshire, where Henry Bolingbroke landed in 1399, and Edward IV. about seventy years afterwards, is now covered by the sea; and Hornsea, another place in the same neighbourhood, once six miles from the coast, now stands on the shore. On the other hand, all along the eastern coast of Italy we have examples of the land gaining upon the sea. The town of Adria, once a flourishing port which gave its name to the Adriatic, is now at least fifteen miles inland.

But not only the form but the elevation of the land is constantly changing. There is evidence to show that the whole east coast of Scotland has been raised twenty feet above its former level since the time that the Romans occupied this island. But in South America we meet with a still more remarkable instance of elevation. In one single night (Nov. 19, 1822) the coast of Chili, for a distance of 100 miles, with the mighty chain of the Andes, including Aconcagua, the loftiest mountain in the New World, was raised from two to seven feet above its former level, the extent of country upheaved being estimated at 10,000 square miles. Some portions of the earth's crust, however, appear to be subsiding. A large tract in the South Pacific, extending from Low Archipelago to Marshall Archipelago, a distance of 4500 miles, and many leagues in breadth, is supposed to mark the site of a former continent, the summits of the submerged mountains forming the centres of lagoons and atolls. A similar area of subsidence is met with in the Indian Ocean, and also in the Coralline Sea, off the north-east coast of Australia; and it has been thought by some that the chain of islands stretching from New Zealand to New Guinea once formed the eastern and northern boundary of the Australian continent. But it is principally in these regions that the coral zoophyte is busy building its reefs, and thus counteracting in some measure the subsidence of the land. The South Pacific is studded with coral islands, but perhaps the barrier reef off the north-east coast of Australia is the grandest coral formation existing. It extends 1000 miles along the coast, at a distance of from 20 to 30 miles from the shore, and its breadth varies from 200 yards to a mile.

All these changes are great in themselves, and should the agencies by which they are produced continue at work during immense periods of time, the distribution of land and water would probably undergo changes as great as any which geology seems to indicate; but the interval which has elapsed since the creation of man is so short when compared with the vast periods which must have elapsed before his appearance on the earth, that, speaking generally, we may say that the present distribution of land and water is the same as it was when man was first placed upon the globe. Now, as it appears that long previous to his creation, the earth was in a state of preparation for him, we may be sure that the present distribution of the continents, and the general elevation of the surface of the land, are just such as are most suitable for making the earth man's abode; and therefore it will be well to notice one or two particulars regarding this distribution, as well as relating to the form and elevation of the continents.

About three-fourths of the surface of the globe is covered with water; and of the remaining fourth, three parts of the land lie north of the equator. If, however, we draw a great circle through the coast of Peru and the south of Asia, we divide the surface of the earth into two equal parts, one of which contains nearly all the land, and the other the greater portion of the water. And in connexion with this it is curious to note that London is nearly the centre of the terrestrial hemisphere, and New Zealand nearly the centre of the aqueous hemisphere.

Form and Elevation of Continents.—If now we compare the great masses of land among themselves, we shall find that the continents may be grouped into three pairs: —Asia and Australia, Europe and Africa, North and South America. We shall find also that the northern and southern continents have each certain characteristics, and that they present certain contrasts. The northern continents are all much indented; each terminates on the south with three peninsulas; and each has an archipelago of islands attached to it. Of course, in order to make this parallel hold, we must suppose the continent of America severed across the isthmus of Panama, and Central America would thus form one of the peninsulas. The southern continents are all compact in form; they each terminate on the south in one point, near which extremity there is an island; and they each have a large bulge, or deep bend, on their western sides.

The forms of the land-masses, of course, determine the forms of the great oceans: and thus we find the Pacific Ocean is rather oval in form, but widens towards the south; the shape of the Indian Ocean is triangular, with the apex of the triangle split by the peninsula of Hindostan; while the Atlantic, as Humboldt remarked, is valley-like in shape,—the opposite shores seem, as it were, to correspond to each other.

If we now turn our attention to the elevation of continents we shall also find certain general principles at work. The six continents seem constructed on three different plans: there is a similarity of structure in Europe and Asia, in North and South America, and in Africa and Australia. In the first pair the chief mountain-ranges run east and west; in the second, north and south; in the third, the mountain-chains lie round the coast. Africa and Australia at one time seem to have contained large inland seas, the remains of which appear in the large shallow lakes of Central Africa, and in the swamps and marshes which are found in the interior of Australia. Turning now to the other four continents, we find that they all rise gradually from the shores of the sea towards the interior, to some point of highest elevation. This line of elevation is never in the centre, but nearer one side of the continent than the other; and from this result two slopes unequal in length and in inclination. In the Old World, the long slope is always towards the north; the short one to the south. In the New World, the long one is towards the east; the short one towards the west. In Europe and Asia the long chain of mountains which divides the two slopes extends, with but slight interruptions, from the Atlantic to the Pacific, and is known under the various names, given to it in different parts, of Pyrenees, Alps, Balkans, Caucasus, Paropamisan Mountains, the Hindoo Koosh, and the Himalayas. In America the division is formed by the Andes and Rocky Mountains. Upon the average the long slope is five times the length of the short one.

Another point worthy of notice is, that the absolute height of mountains is found to increase with the elevation of the table-lands on which they stand. Thus the plains of Siberia at the foot of the Altai Mountains have an elevation of about 380 feet, while the Altai chain has an altitude of 11,000 feet: the base of the Kuenlun is about 5000 feet above the sea-level, while the chain itself attains the elevation of 20,000 feet. Still further south the plateau of Thibet reaches the altitude of 14,000 feet, and the Himalayas in some peaks reach 30,000 feet. Turning now to the New World we find the same law prevailing. The valley of Virginia in North America is about 300 feet above the level of the sea, while the Appalachian mountains attain 6000 feet. Farther west, at the foot of the Rocky Mountains, we find Fort St Vrains situated 5000 feet above sea-level, while the mountains themselves attain the height of 12,000 feet.

We have mentioned that in the Old World the slopes are north and south; in the New World, east and west; but in both Worlds the two laws exert their influence. Thus, in the great continent of Europe and Asia, though the main slopes are north and south, yet, commencing with the Himalaya Mountains, the elevation of the continent decreases to the east and west; and in the New World, besides the great slopes to the east and west, we find two secondary slopes to the north and south. We may sum up the foregoing remarks, on the elevation of the land-masses, in two important conclusions:—

1. Generally speaking the elevations go on increasing from the poles to the tropical regions. The greatest elevations, however, are not at the equator, but in the neigh-

bourhood of the tropics: near the tropic of Cancer, in the Old World (the Himalayas 27° north), and near the tropic of Capricorn, in the New World (Lirima 23° south).

2. All the long and gentle slopes descend to the Atlantic; all the short and rapid slopes, to the Pacific and Indian Oceans.

Depth of the Oceans.—It was at one time supposed that the average depth of the ocean was equal to the average elevation of the land; but this was a mere supposition. Great difficulties presented themselves at every attempt to fathom what sailors call "the blue water," and after several failures the results at length obtained were open to considerable doubt. Lieutenant Walsh, an American, reported a cast of 34,000 feet between the Bermudas and Azores, without finding a bottom. Off the mouth of the La Plata, Captain Denham reported a depth of 46,000 feet; while Lieutenant Parker sounded with a line 50,000 feet, near the same region, without having reached the bottom. He was engaged in this experiment eight or nine hours, and night coming on, he attempted to haul in the sounding-line, when it broke. The usual method of sounding is this: a cannon ball weighing thirty-two or sixty-eight pounds is attached to the end of a sounding-line. This line is made of twine prepared for the purpose, carefully marked at every length of one hundred fathoms, and wound on reels of ten thousand fathoms each. The ball is dropped into the water and the line allowed to run out freely: and it was supposed that when the plummet reached the bottom, the line would cease to run out; and then by breaking off the twine, and counting the number of fathoms left, the quantity given out could be calculated. But when lengths of forty or fifty thousand fathoms were given out without apparently having reached the bottom, it was suspected that the line must have been carried away by under-currents: and this suspicion was strengthened by the fact, that the twine parted the moment it was prevented running out by being made fast to the boat.

After considerable care and trouble, the *law of descent* was established, and according to this law, the line on being dragged down by the ball, runs out at a decreasing rate. Thus:—

2′ 21″ was the aver. time of descent from 400 to 500 fath.
3′ 26″ „ „ „ 1000 to 1100 „
4′ 29″ „ „ „ 1800 to 1900 „

Now, as under-currents would cause the line to run out at a uniform rate, it will be evident that by carefully noting the rate at which the line ran out, it might be ascertained when the ball had reached the bottom, for then the line would begin to run out regularly.

By attending to the law of descent it has been found that the depths mentioned above are much too great, and that the deepest part of the Atlantic is probably south of the Great Banks of Newfoundland, and there the depth does not exceed 25,000 feet. Now that deep-sea soundings may be made with some approach to accuracy, we may expect to see a new feature in physical geography, and no doubt in time we shall be as well acquainted with the elevations and depressions of the bed of the ocean as we are with the surface of the land. Lieutenant Maury has already constructed a map of the basin of the Atlantic, and similar maps will no doubt from time to time appear, as our knowledge of this subject is extended. The most interesting feature in the bed of the Atlantic is the telegraphic plateau. This is a ridge of land extending from Cape Clear, in Ireland, to Cape Race, in Newfoundland; the distance is about 1640 miles, and the depth is nowhere more than from ten to twelve thousand feet. It is along this ridge that the telegraph between Europe and America is laid; and although for the present this cable is useless, it is gratifying to learn from the highest authority that we may hope—due regard being paid to the construction of the cable and to the method of laying it down—yet to see telegraphic communication between the Old and New Worlds.

CHAPTER VII.

THE ATMOSPHERE—ITS USES.—WINDS.—EFFECT OF THE DISTRIBUTION OF LAND.—MONSOONS.—VARIABLE WINDS.

We have hitherto spoken only of two divisions of our globe, land and water; but there is a third division—the air—which is not less important than either, since without it, neither vegetable nor animal life could exist: it is also the medium for distributing the light and heat which we receive from the sun, and upon it depend every beauty of colour and every variety of sound. The air, or atmosphere, as it is called, entirely envelops our globe, and extends to a distance of from 50 to 100 miles from its surface. As it is subject to the law of gravitation, and is also a highly elastic fluid, the lower strata of air are pressed down by those above them, and hence are much denser: from this it follows also that the atmosphere exerts a certain pressure upon the surface of the earth, and this is found by experiment to be about 15 lbs. to a square inch. It has been calculated that the amount of the pressure of the atmosphere upon a man's body would be sufficient to break the back of a horse: but this force is counterbalanced by the air inside the body; for every vessel and tube is filled with it. Travellers, however, who have ascended very high mountains, such as the Alps, feel this balance destroyed, because the upper strata of air are much less dense than the lower, and hence bleeding often commences at the nose, eyes, and ears.

We derive our light and heat from the sun. When a ray of light strikes upon any body, part of it passes throught it, part of it is reflected back, and part of it is lost and dispersed. This is the case upon whatever kind of body the light may strike; for though we call those bodies transparent through which light passes easily, yet a small portion of it passes through opaque bodies: and on the other hand, even in transparent bodies, all the light is not transmitted,—part is reflected, and part dispersed and lost. When a ray of light passes obliquely from a rare into a denser medium, it is bent from its course, and this change in its direction is called **Refraction.** Now, as the atmosphere is a denser medium than void space, and as different portions of the air differ in density, it happens that the light proceeding from the sun, moon, or stars, is *refracted* in coming to us, unless these bodies are in the zenith; and, as objects always appear in the direction in which rays from them strike the eye, the effect of refraction is to make the heavenly bodies appear to have a greater altitude than they have really, and this must be taken into account by astronomers in all their observations.

When the light from the sun strikes upon our atmosphere, part of it is reflected back, and part of it is refracted and proceeds through the air; and as it advances into media more and more dense, other portions are reflected and refracted, and when it strikes the surface, part of it is again reflected back and absorbed. It is to this constant reflection from different particles of the atmosphere, and from material objects, that we owe the broad light of day. Were there no atmosphere, or did it not possess the property of reflecting and dispersing light, there would be no light, except directly in a line with the rays of the sun; all objects out of the direct influence of the rays would be wrapt in total darkness. Another important result of reflection is **Twilight.** When the sun is a little below the horizon, just before sunrise, or a little after sunset, his rays, shooting up into the atmosphere, are partially reflected back upon the earth, and afford a faint daylight.

The white light of the sun's rays is made up of three different colours—red, yellow, and blue, and these coloured rays are differently affected in passing through any medium. Some objects absorb one or more of these rays, and reflect the others, and upon the colour of the reflected light depends the colour of the object. Thus, all the different varieties of colour depend on the reflection of light. We have seen that when light strikes the surface of the earth a portion of it is reflected. Of this reflected light the red and yellow portions struggle back through the atmosphere, while the blue is again reflected back to the earth, and hence the blue appearance of the sky. Travellers, on ascending high mountains, find the sky get blacker and blacker: for as the air becomes more rare, there are fewer particles to reflect back the blue light.

The sun's rays convey to us heat as well as light; hence, as the rays are dispersed throughout the atmosphere, heat is diffused at the same time. Now, the more dense the air is, the greater will be the amount of heat which it will contain, and thus the tops of mountains are always cold, for there the air is much more rare than at the surface of the earth. This fact shows the importance of considering the elevation of surface in any particular case, for upon the elevation depends, in a great measure, the temperature. It has been calculated that an elevation of 350 feet makes a difference of one degree Fahrenheit, or, in other words, it is almost equal to a removal of one degree nearer to the poles.

We have already said that the atmosphere is the medium of sound: without it there would be a deathlike silence, for all sound depends upon the vibrations of the air. All fluids transmit sound, some even better than air, and there are some kinds of wood which convey the vibrations nearly seventeen times as rapidly as air; but still these media can only be available by actual contact, and therefore it is upon the atmosphere that we must depend for the sound, however produced; and without it the sweetest strains of music would be silent,—nay, conversation even would be impossible.

Such are some of the uses of the atmosphere, even in a quiescent state. It is necessary to the existence of life; it disperses light and heat; it is the cause of sound. When set in motion, we see it performing other offices equally important. Winds convey heat and moisture from one part of the earth to another, and form a powerful agency for assisting man in mechanical skill and commercial enterprise.

Winds.—We have already stated that the atmosphere presses upon every part of the earth's surface with a weight of about 15 lbs. to a square inch; and that the lower strata of air, being pressed down by those above, are denser and heavier. Heat expands air and makes it lighter; it then ascends until it reaches a stratum of its own density. If, therefore, any portion of the atmosphere becomes heated, it rises, and leaves a vacuum; the surrounding air then rushes in to fill up the vacuum and produce equilibrium: a current of air is thus formed, and this current we call *wind.*

Were the earth entirely covered with water, and the atmosphere everywhere of the same temperature, there would be no wind. If, however, the tropical parts of the earth were heated, as they are now, the air in these regions would become rarefied and ascend, and we should have a current from each pole towards the equator. These **Polar currents**, however, would necessitate return currents to supply the vacuum caused at the poles, and these return currents, consisting of warm rarefied air, would be upper currents; while the cold currents from the poles would be surface currents.

The diurnal motion of the earth would alter the direction of these winds somewhat. The earth, in turning on its axis from west to east, carries the air along with it, and imparts its own motion to it. As was before mentioned (page 18), the equator is a great circle, and all circles drawn parallel to it must decrease in circumference as they approach the poles; therefore, in one diurnal revolution, any spot upon the equator must describe a greater circle than any other spot nearer the poles, and must therefore move with greater velocity. And since the earth imparts its motion to the surrounding atmosphere, the air at the equator must move from west to east with greater velocity than the air nearer the poles. If, therefore, a current of air comes from the poles to the equator, as it approaches the tropics it will move from west to east more slowly than the earth does; it is therefore left behind, and, as a consequence, *appears* to move in the opposite direction—that is, from east to west. Thus, instead of having winds directly from each pole to the equator, we have them blowing from the north-east and south-east; and, when they have reached the tropics, their direction is almost entirely from east to west, and they are termed **Trade winds.** For the same reason the *return* winds to the poles blow from the south-west and north-west, instead of directly from the south and north.

The ascending current of warm air at the equator will rise, as has been said, until it meets with a stratum of its own density; it then turns northwards or southwards as a return wind, and is gradually cooled. As it cools it becomes denser, and therefore heavier; it then gradually descends, and, at about 30° on each side of the equator, touches the surface of the earth. We thus have a regular and complete circulation in the air: currents flow from either pole to the equator, then rise and flow back to the poles; and the polar and return winds, as we have seen, cross at about 30° on each side of the equator. It has also been proved that the winds cross at the equator—that is, it is the current from the north pole which forms the return current to the south pole, and *vice versâ.* Near Cape Verde Islands, and in the Mediterranean, sailors have frequently met with showers of red dust. Portions of this dust were analyzed by Ehrenberg, an eminent German chemist, and from the organic remains discovered in it, he was convinced that this dust came originally from the basins of the Amazon and Orinoco, regions south of the zone of calms.

We have seen, then, that if the earth were entirely covered with water, and there were no land to break and change the direction of atmospheric currents, that, owing to the combined influences of the heat of the sun and the diurnal motion of the earth, we should have a constant and regular circulation of air. North-east and south-east winds would move towards the equator, gradually assuming more of an easterly course as they approached the tropics; and **Return currents** of air would flow back towards the poles. We have seen also that the polar winds cross each other at the equator, and that the polar and return winds cross near the tropics. Hence we have three **Calm belts**, each extending right round the globe, except where broken and interrupted by local causes. The first is the belt of equatorial calms, where the north-east and south-east trade winds meet; for there the *ascending* currents neutralize the horizontal currents: and at about 30° on each side of the equatorial belt, are the belts of Cancer and Capricorn, where the return winds and polar winds meet.

We have next to consider how the winds are modified by the distribution of land. And, in the first place, we notice that the zone or belt of south-east trades is broader than the belt of north-east trades; and that the equatorial belt of calms does not in fact coincide with the equator, but lies a little to the north of it. This is owing to the preponderance of land in the northern hemisphere. For owing to this circumstance the *thermal* equator, or line of greatest heat, lies to the north of the terrestrial equator; and as the ascending current of warm air will always be at the line of greatest heat, we find the trade winds range themselves on each side of the *thermal* equator. Again, the large deserts of Africa and Asia act as a check upon the north-east trade wind; for the air over these barren tracts being extremely rarefied, especially during summer, a portion of the north-east trades is required to restore equilibrium. Evidence of this fact is seen in the character of the two trades. For the south-east trade wind is much stronger and "fresher" than the north-east, and hence is not so much influenced by the rotation of the earth. Thus, while the north-east trade winds, in their general course, make with the equator an angle of 23°, those of the south-east make an angle of 30° or even more.

Monsoons.—So great, indeed, is the influence of the arid plains and deserts of Africa upon the trade winds, that during the months of summer and autumn, the north-east trade is not only checked, but even turned back, and blows over the deserts of Africa; while the south-east trade, meeting with no opposition at the equator, crosses the line and, continuing northwards, is changed into a south-west wind, and forms a monsoon. For a similar reason periodical winds exist on the west coast of Mexico. But it is in the Indian Ocean where the monsoons are most perfectly developed. In summer, when the sun is north of the equator, the heated plains of Asia rarefy the air above them, and to restore equilibrium the south-east trade wind is turned back and formed into a south-west monsoon. Between October and April the sun is south of the equator, and hence there is a rush of air towards the south of Africa, and the north-east monsoon prevails. These winds blow with great regularity, and hence their name, which signifies *season.*

We have already remarked that the equatorial belt of calms or "Doldrums," as it is called, coincides with the line of greatest heat; now, as the sun moves northwards and southwards in the tropics, this line of greatest heat will not be stationary, but will follow the sun, and, as a consequence, we find that the "Doldrums" move northward from May to September, and southward between September and May. Of course, this movement affects the other belts of calm, and therefore the position on the earth's surface where the return winds begin to prevail as surface winds will vary with the seasons. These winds will approach nearer to the poles, before they reach the surface, in summer than in winter. This is an important fact, as will be seen when we come to speak of the distribution of rain.

In the north Atlantic, sailing packets from America to Europe have performed the voyage in from 20 to 23 days, while the same vessels, in a voyage from Europe to America, generally require from 35 to 40 days; the difference being caused by the prevailing south-west winds. As these winds are warm and moist, while the north-east winds are cold and dry, we cannot but admire that beautiful dispensation of Providence which causes these winds to be the means of mitigating the rigour of our northern climate, and of fertilizing the land with copious showers. The constant struggle between the north-east and south-west winds is the cause of those frequent changes, in direction, of the winds so generally felt in temperate and polar regions; and hence these parts are known as the regions of *variable* winds, just as the torrid zone, where the trade winds and monsoons prevail, is called the region of *permanent* and *periodical* winds.

CHAPTER VIII.

RAINS.—THEORY OF RAINS.—DISTRIBUTION IN TROPICAL REGIONS—IN TEMPERATE REGIONS.—DEW.—SNOW.

Vapour is constantly rising from every portion of the surface of the earth, at all times and at all temperatures; and this vapour is absorbed by the atmosphere. When the vapour is condensed and made visible, it is called *rain* or *dew*, according to the manner of its deposition; or if the cold which condenses it be very great, *snow* is formed. Cold air can hold less vapour in solution than warm air. When, therefore, a portion of the atmosphere is saturated, that is, has as much moisture in solution as it can possibly contain, if it be then heated, its capacity for holding moisture is at once increased, and it is enabled to take up more: if, however, its temperature be diminished, its capacity is lessened, and the superabundant moisture is condensed, and becomes visible. Thus, if a warm current of air, laden with moisture, comes in contact with a colder current, rain is freely deposited; if, on the other hand, a cold current of air, laden with clouds, meets with a warmer current, the clouds are sometimes dissipated, and the air cleared.

It thus appears that rains depend in a great measure upon winds; where the latter are regular so are the former; where winds are changeable, rains are irregular. Let us now apply these principles to the tropics. When the sun approaches the zenith of any place in this region, the ascending current of air becomes very strong, and carries large quantities of vapour up with it. As this current passes into colder strata of air, part of the moisture held in solution is condensed, and falls in heavy rains. And as the sun is *twice* over the zenith of every place within the tropics in the course of a year, it follows that there are two rainy seasons at these places, though the first is the most important, and lasts four months, while the second lasts only six weeks.

In districts where the monsoons prevail, these winds determine the rainy season. Hence the eastern and western coasts of Hindostan have rainy seasons at different parts of the year—one coast depending on the north-east monsoon, while the other depends on the monsoon from the south-west. Countries beyond the tropics depend generally upon the return winds for their moisture. Sub-tropical regions,—that is those regions immediately beyond the tropics,—are generally deficient in moisture. For they are not within the influence of the trade winds, and the return winds are scarcely felt. Thus we can explain the slight rains of Australia and the Cape; and partially account for the deserts of Africa and Arabia. On the other hand, the equatorial belt of calms is a zone of almost constant precipitation. There the ascending currents of air are constantly carrying up into colder strata quantities of moisture, part of which is at once condensed, and falls in the form of rain, and part is carried north and south by the return winds; hence the copious rains of Senegambia and Guinea.

As a rule, rain is much more abundant within the tropics than in temperate regions, for there the evaporation is much greater, owing to the excessive heat. Upon an average 97 inches of rain fall annually within the tropics; while in temperate regions the annual fall is only about 35 inches. Owing to local causes, however, the quantity of rain that falls in some places far exceeds these figures. On the southern slope of the Khasia Mountains, in Bengal, 600 inches have fallen in one year; in Sierra Leone, 400 inches; and 300 inches have been noticed at Mahabaleshwar in the Western Ghauts, a little south of Bombay. Even in temperate regions the annual quantity is often very great: Seathwaite, in the heart of the Cumberland Mountains, is perhaps the wettest place in Europe; the fall here is about 146 inches annually. It may be remarked, that as regards both tropical and temperate regions, the New World has a climate much more moist than the Old World.

The higher we ascend into the air the colder it becomes. Rain is formed, as we have seen, when a stream of warm air comes in contact with a colder one; for then the vapour held in solution by the warm air is condensed. Hence we can explain how it is that so much rain falls in mountainous districts,—in Seathwaite, for example. For, suppose a wind laden with moisture to strike against the side of a mountain, in order to pass this obstacle it must ascend; the current is thus forced into a colder stratum, and the moisture in it is condensed, and perhaps falls as rain. Of course, a good deal will depend upon the amount of moisture contained by the warmer current; if the air is almost saturated, then most likely rain will be formed; if, on the other hand, the air does not contain much moisture, the vapour will perhaps be condensed into mist or clouds without the formation of rain. Neither do clouds always deposit the whole of their moisture; it is the *excess* which is precipitated. From these remarks it will be evident that in order to understand the general distribution of rain, we must consider the irregularities of the earth's surface, its plains, plateaus, and mountain-chains. Commencing, therefore, with the tropics, where the rains are most regular, we find the trade winds, laden with moisture, sweep across the Atlantic and strike upon the coasts of Brazil, Guiana, the West Indies, and Florida: all these coasts are well watered. The winds continue their course across Southern and Central America, and meeting with the Andes are still further drained of their moisture; but in Mexico the mountains are not high enough to extract moisture from the trades, and hence they pass over the country and scarcely deposit one drop. Continuing their course across the Pacific, the trade winds come in contact with the coast of China, the Eastern Archipelago, and the northern parts of Australia; and here again abundant rains are found.

In the Indian Ocean the monsoons prevail, and the two coasts of Hindostan have rainy seasons at opposite periods of the year. Along the eastern coast of Africa, a chain of mountains runs from the equator to the Cape, and this chain extracts the moisture from the north-east monsoon, and prevents it from carrying its abundance of rain into the central regions of Southern Africa. We have already mentioned that the Guinea coast is in the zone of calms, and this alone would account for the quantity of moisture it receives; but we must also recollect, that in certain periods of the year a monsoon prevails on this part of the western coast of Africa (p. 50), and this monsoon is the principal *rain wind* of this region.

On the western coast of America there are two rainless districts,—the plateau of Mexico, and the desert of Atacama. The former we have already noticed, the latter is also deserving of attention. Owing to the altitude of the mountains which bound the desert of Atacama on the east, the trade winds are deprived of every drop of their moisture before they pass across them; and the moisture which arises from the adjacent waters of the Pacific is carried *away* by the trade winds; hence Atacama is rainless. Further north the mountains decrease in altitude, and the winds are enabled to convey some of their moisture across them: further south the return wind prevails, and, coming from the north-west, carries moisture to the coasts of Chili; here again, however, the Andes interpose themselves, and the north-west wind, being deprived of its moisture, is changed into the dry *Pampero*, which sweeps across the plains of Paraguay and the deserts of the Pampas. The plateau of Mexico, as has been already indicated, owes its drought to the character of its surface. The north-east trade wind has been deprived of a great portion of its moisture in passing the West India Islands, and a little more is deposited when the wind strikes upon the edge of the table land; but, in sweeping across the plateau, there are no mountains of sufficient elevation to extract the remaining moisture, and thus the wind passes without yielding one drop. This is the case more or less with all plateaus and elevated plains, and hence we can account for the arid character of the interiors of Spain and Arabia, the plateau of Iran, and the desert of Cobi, in Central Asia. The Sahara of Africa is closed on the east from trade winds and monsoons, and this, combined with its sub-tropical position and the nature of its soil, makes it a complete desert.

Temperate regions depend for their moisture upon *return* winds, hence the western coasts of continents receive more rain than the eastern coasts. British Columbia, on the north-west coast of America, like Great Britain itself, has copious and abundant rains, and owing to the same cause,—its position on the western side of a continent. It has been stated that the return winds first strike the surface about 30° on each side of the equator, at the calm belts of Cancer and Capricorn; and it has been mentioned, also, that these belts are not stationary, but vary somewhat, moving northward between May and September, and southward between September and May. Now, as we have already intimated, these return winds are the *rain winds* of temperate regions, and of course a great portion of the moisture will be deposited where these winds first strike the surface. As, therefore, the return winds strike the surface at different places in different seasons of the year, we can understand how at one place we have winter rains prevailing, at another spring and autumn rains, at another summer rains. Thus, at the Cape, and in Southern Australia, we have autumn and winter rains; in Central Europe there are summer rains; in Southern Europe autumn rains; while winter rains prevail on the north coast of Africa.

A few general remarks will finish this subject. The annual amount of rain in the north temperate zone is half as much again as in the south temperate zone. Now, although we can see how beneficial this is, seeing that three-fourths of the entire land lie in the northern hemisphere (p. 39), still we cannot at first sight explain the fact: for, of course, more evaporation must take place in the southern hemisphere, where there is so much more water, than in the northern. And, indeed, it is so; but all this moisture is transferred to the northern hemisphere; for we have already seen that it is the south-east trade wind which forms the return wind to the north, and this return wind we have also seen is the rain wind for the north temperate regions.

Within the tropics very little rain falls upon the ocean. This we can readily understand, since there are no obstacles in the ocean, like mountain-chains, to condense the moisture carried along by the trade winds, but we cannot but notice the beneficial results of this, since the land which has the most need of the rain gets the most of it.

Though more rain falls in the tropics than in temperate regions there are fewer rainy days. This, again, is a beneficial arrangement; for if in temperate regions there were such long droughts as there are within the tropics, everything would be dried up for want of moisture. The reason of this may be easily explained. It has been mentioned that the higher the temperature of the air is, the greater is its capacity for containing moisture (p. 51), hence the atmosphere in tropical countries contains much more moisture than in temperate regions; now as this moisture is taken in by the leaves of plants along with the air, it follows that they can exist a longer time without rain than they could in temperate regions. It is owing to the excessive moisture contained in the air of warm countries that those copious dews are formed, which also supply the want of rain. In our climate there is actually less moisture in the air in the damp raw days of January than in the bright clear days of July; but in the former case the moisture is condensed by the cold, and becomes sensible.

Dew.—The formation of dew is analogous to, though not identical with, the formation of rain. During day-time the earth and the atmosphere are both heated by the rays of the sun, and the air becomes loaded with the vapour which rises from the ground. But after sunset the earth cools very rapidly, and condenses the air with which it is immediately in contact. The air thus cooled can no longer retain its abundance of moisture, and part of it is deposited in the form of dew. Hence, in hot countries, where the quantity of moisture contained in the air is very great, the amount of dew deposited is very heavy, and this dew is of service in the long droughts as we have already mentioned, and in some cases makes up for the total absence of rain. It may also be remarked, that as the leaves of plants and trees radiate heat quicker than stones and gravel, so the amount of dew deposited on the former is much greater than on the latter, and this is another of the many beautiful arrangements we meet with in studying the laws by which Nature is governed.

Snow.—When the cold which condenses the moisture contained in the atmosphere is very great, snow is formed instead of rain. Snow generally consists of minute crystals, varying in form according to the degree of cold; and the whiteness of snow is owing to the light reflected from the numerous faces of these minute crystals. As the formation of snow depends upon a very low temperature, it is not found within the tropics, except at a very great elevation. In the southern hemisphere, owing to the preponderance of water, winters are not so severe as in the northern hemisphere, hence there, at the sea-level, snow is not found so near the equator as in the northern hemisphere In the northern hemisphere the line which marks the southern limit of snow runs from Canton in China, along the north of India, through the Mediterranean to the Gulf of Mexico; in the southern hemisphere it does not approach nearer the equator than the south of Australia, the Cape Colony, and Patagonia. As it becomes colder the higher we ascend into the atmosphere, even within the tropics the tops of some mountains are covered with perpetual snow. Upon an average the line of perpetual snow has an elevation of about 16,000 feet within the tropics, and descends as we approach the poles. In the Alps and Pyrenees it is about 8000 feet; and at the island of Mageroe, in the north of Europe, it descends to 2000 feet. Snow is of great use in protecting the ground, which it covers, from severe frosts; it prevents the earth from radiating too quickly, and defends it from piercing winds. In Siberia the difference between the temperature of the ground beneath the snow and that of the air above it has sometimes amounted to 48° Fahrenheit.

CHAPTER IX.

OCEANIC CURRENTS.—THE EQUATORIAL CURRENT.—THE GULF STREAM.—THE PACIFIC GULF STREAM.—THE OPEN SEA IN THE ARCTIC OCEAN.—THE SALTS OF THE OCEAN.—TRADE ROUTES.

Currents in the ocean depend upon the same causes as currents in the air; hence, if we understand the theory of winds, we shall have no difficulty about oceanic currents. The waters within the tropics being greatly heated, evaporation, as we have already mentioned (p. 52), takes place to a considerable extent. To supply the vacuum caused by evaporation, as well as to restore the equilibrium destroyed by the waters at the equator becoming heated, and therefore lighter, cold currents will flow in from the north and south. And thus, as with winds, we might expect a cold current from either pole, an equatorial current, and return currents to the poles. The normal character of these currents must also be considerably modified by the distribution of land, though to a much greater extent than in the case of winds.

Commencing with the Pacific Ocean, we find that in the great southern basin various cold currents flow from the Antarctic regions northward. One of these washes Van Diemen's Land and the south parts of Australia; another reaches Cape Horn, where it then splits, one branch flowing round the cape to the east, while the other proceeds up the western coast of South America, and at length mingles its waters with the great equatorial current. This current, which by some has been named after Humboldt, is much colder than the waters of the neighbouring ocean, and off Lima the difference in temperature is said to amount to 20° Fahrenheit. The **Equatorial current** sweeps across the Pacific with a speed ranging from 30 to 35 miles a-day, and extends in a broad belt on each side of the equator, with a breadth of about 50°.

On reaching the chain of islands which stretches between Asia and Australia, the equatorial current is broken up into several channels, and struggles through into the Indian Ocean. Here it is acted on by the monsoons, and its course checked; but a portion continues its course to the west, and striking the large island of Madagascar, splits: one branch rounds the northern extremity of the island and flows southward through the Mozambique Channel, the other flows south-west and joins the **Mozambique current** at the Cape. Off the Cape a large sandbank—the Agulhas bank—has been formed, stretching more than 500 miles from east to west, with an average breadth of 100 miles. Between this bank and the mainland, the **Cape current** flows, and on entering the Atlantic it is met by another current which sets in from the north-west. It therefore divides: a part returns with the Atlantic current into the Indian Ocean, while the other part flows north-west along the western coast of Africa, and joins the great equatorial current of the Atlantic.

The equatorial current in this ocean flows from the Gulf of Guinea across to the continent of South America, which it reaches near Cape St Roque. Here, owing to the direction of the coast, it divides: one branch turns southward along the coast of Brazil, while the other washes the north coast of South America, and having passed the shores of Guiana enters the Caribbean Sea. A branch of the Brazil current turns south-east across the Atlantic, and, under the name of **South-connecting current**, enters the Indian Ocean, while another branch, as we have already seen, meets the Cape current on its entrance into the Atlantic. The Guiana current, after passing through the Caribbean Sea, follows the shores of the Gulf of Mexico, and emerges through the Strait of Florida under the name of the Gulf Stream.

The Gulf Stream.—This current can be easily distinguished from the waters of the surrounding ocean by its colour—a deep indigo,—its high temperature, and its speed. On leaving the Gulf of Mexico the stream is of no great breadth, but of considerable depth, as has been proved by soundings: there is little change of temperature even at the depth of 3000 feet. The warmer waters, however, being light, gradually ascend and spread themselves over the surface, so that off Cape Hatteras it spreads across the Atlantic and reaches the Azores. Here a large portion of the stream turns southward, and having bathed the shores of Portugal and Africa, mingles its waters with the great equatorial current in the Gulf of Guinea. The other division of the Gulf Stream proceeds to the north-east, washes the shores of the British Islands, and proceeds along the coast of Norway as far as the latitude of North Cape. Here, meeting with a cold current from the Arctic Ocean, the stream divides; one branch rounds North Cape and loses itself in Varanger Fiord; the other continues its course to the north, bathes the west coast of Spitzbergen, and gradually mingles with the waters of the Arctic Ocean.

Besides the cold current already mentioned, there are at least two others in the North Atlantic, which flow southward to supply the place of the waters conveyed away by the Gulf Stream. One flows along the coast of Greenland, and the other comes down Davis Strait, washes the shores of Labrador and Newfoundland, and is felt as far south as New York. The waters of these currents being cold and heavy, gradually sink as they move southward, and exist as under-currents. Hence huge icebergs, carried along by these invisible currents, sometimes stray as far as the 40th parallel.

The Pacific Gulf Stream.—The waters of the Indian Ocean are hotter than those of the Gulf of Mexico, and therefore, as might be expected, many warm streams leave this ocean, while cold ones, principally from the south, enter it. One of the warm streams, in its direction and character, very much resembles the Gulf Stream of the Atlantic. It flows through the strait of Malacca, turns north-east between Borneo and the coast of China, and being joined by a part of the great equatorial current of the Pacific, flows northward along the east coast of Japan, and enters the sea of Kamtschatka. A branch of the current now passes through Behring Strait into the Arctic Ocean; but the greater portion of it sweeps past the Aleutian Islands, and down the west coast of North America. By the time this current has reached California, in its progress to the south, it has lost much of its warmth, and gives a refreshing coolness to the sea-breezes of that coast, in the summer time.

As Behring Strait is too shallow to admit of under-currents, there is no cold current through it corresponding to the current on the east coast of Greenland. But the cold current which, flowing from Davis Strait, washes the east coast of North America, has its counterpart in a cold current from the Sea of Okhotsk, which washes the west side of the Japan Isles, and flows southward between the China or Gulf Stream of the Pacific and the eastern shores of Asia.

The Open Sea in the Arctic Ocean.—It is the custom of whalers to mark their harpoons with the date and name of their ship; and sometimes whales have been caught in the Pacific, near Behring Strait, with harpoons in them bearing the stamps of ships which were cruising, not long before, in Baffin's Bay. The question naturally arose, How have these whales crossed from the Atlantic to the Pacific? In some cases the short interval that had elapsed precluded the idea of the whales having passed round by Cape Horn; and even if time had not been wanting, it is well known that whales cannot exist in the warm waters of the tropics, and therefore could not possibly pass from the North to the South Atlantic. Neither could it be supposed that the whales had passed under the ice which closes up the Arctic regions, for they cannot exist so long under the ice as such a passage would require. The only supposition left was, that there must be water communication somewhere through the Arctic Sea, from one side to the other. What made this supposition the more probable was, that it was well known that there was a current flowing through Davis Strait into the Arctic Ocean, as well as one flowing southward; for navigators in these seas have observed large icebergs drifting northward against a strong surface current flowing in the contrary direction. Now, this current northward, as it comes from the south, must be warmer than the one coming out of the Arctic Ocean, and it was argued that there must be some place where the warm waters of this under-current would come to the surface; and wherever this place might be, the severity of the climate must, to some extent, be mitigated by these warm waters. Hence, when Lieutenant De Haven was sent out in command of an American expedition to search for Sir John Franklin, he was instructed to look out, when he had proceeded up Wellington Channel, for an open sea to the north and westward. He looked, and saw in that direction a "water sky." Dr Kane was still more successful. He and his party, having crossed a barrier of ice 80 or 100 miles in breadth, came upon an open sea north of the parallel of 82°. As far as the eye could reach was a sheet of water, the waves of which dashed on the beach with the swell of an ocean. The tides ebbed and flowed in it. Though just before reaching this sea the thermometer was at —60°, yet the water itself had a temperature of 36°; water-fowl were feeding, and seals sporting about. —[*Maury: Physical Geography.*]

The Salts of the Sea.—It is well known that the sea is salt; and although some parts of the ocean differ from others in saltness, the difference is never great. The solid parts of sea water amount to nearly 3½ per cent. of its weight, and therefore, taking the average depth of the ocean at two miles, we may calculate that its waters hold in solution about seven millions of cubic miles of salt: and all this solid matter is received into the interstices of the sea water without swelling the mass. We may be sure, from what we know of the harmony in nature, that the presence of salt in the ocean is for some wise purpose; and it suggests itself at once to every one, that in conjunction with the tides and currents of the ocean, salt helps to keep the waters fresh and free from corruption; but it appears that it also gives vigour to the currents themselves, and assists and regulates evaporation.

In speaking of the origin of oceanic currents, we assigned two causes—the vacuum caused by evaporation, and the difference in density between the warm waters of the tropics and the cold waters of extra-tropical regions (p. 59); the presence of salt is a third cause. Fresh water contracts in cooling until it reaches 40°, when it begins to expand, and continues to do so unto the freezing point. Salt water, on the contrary, only expands through heat. When salt water is exposed to heat, it is mostly fresh water that is evaporated—the salts are left behind: hence the surface water descends, and other water rises to the surface. The water that has been evaporated is carried away by winds, and deposited in the form of rain in other regions. Now, as in tropical regions the evaporation is in excess of precipitation, and as in extra-tropical regions, as a rule, the contrary holds: through time, unless some compensating cause was at work, we should have the waters of the tropics containing a superabundance of salt, while the polar regions would have a superabundance of fresh water. But there is a compensating cause at work in the form of under-currents, an example of which we find in the one which flows through Davis Strait into the Arctic Ocean. And we can understand now, how that being a warm current was yet an under-current, for it was rendered heavy through the abundance of the salt it contained. It is to the salts of the sea, also, that we owe the under-currents from the Mediterranean into the Atlantic, and from the Red Sea into the Indian Ocean.

The presence of salt in the ocean also regulates evaporation. It has been proved by experiments that the salter the water is, the slower is the process of evaporation. Hence, as the trade winds carry off the moisture evaporated, the evaporation goes on slower, and thus excess is prevented. If, however, this process were to continue, evaporation would eventually cease. This is, however, provided for; the water, as it becomes salter, becomes heavier, and therefore sinks; other water less salt then rises to the surface, and evaporation proceeds.—[*Maury.*]

Trade Routes.—The routes pursued by navigators in their voyages to different countries depend chiefly upon the winds and currents; a few of the principal of these routes we shall briefly notice. In going **from Europe to America**, ships generally avoid the Gulf Stream by sailing, beyond its northern limit, between the parallels of 40° and 50°. By this means, on nearing the American coast, they are assisted by the current which flows from Newfoundland to New York. In returning **from America**, the Gulf Stream is of service, though sometimes it is again avoided, on account of the damage which vessels often sustain while in it. The westerly winds which prevail in this part of the Atlantic make the return voyage much shorter than the other. Vessels going **to the West Indies, or to Central America**, direct their course southward, in order to come as soon as possible into the region of the trade winds. They reach the Madeiras, and then, leaving the Canaries to the east, enter the tropics. If the ship is bound **to the Greater Antilles, or to the Gulf of Mexico**, it takes the passage between Guadeloupe and Antigua; if **to the Caribbean Sea**, its course is between Martinique and Trinidad. Vessels returning **from the Caribbean Sea** pass through the Mona Channel, between Hayti and Porto Rico; those **from the Gulf**, go through the Strait of Florida. In both cases advantage is taken of the Gulf Stream, and the passage lies north-west, the ships often touching at the Bermudas and the Azores.

Navigators, when bound **for the Southern hemisphere** generally steer their course, as before, southward to the tropics. Then, under the influence of the trade winds, they approach the shore of Brazil about the parallel of 10° south, after which the coast of South America may be navigated in any direction. If bound **for the Cape or the Indian Ocean**, ships generally steer for the rocky island of Trinidad (lat. 20° 30′, long. 29° W.), and, passing to the west of it, sail with a westerly wind and the South-connecting current to the southern point of Africa. In returning **from the Cape**, a navigator sails with the south-east trade wind to St Helena. Then, crossing the line at about 20° west, he steers for the Azores, and falls in the track from the West Indies to Europe. Ships coming **from South American ports** keep near the coast as far the equator, in order to take advantage of any periodical winds.

Vessels bound **for India or China** sometimes call at the

Cape, though it involves a great loss of time. Their course across the Indian Ocean depends greatly on the monsoons. During the south-west monsoon, a ship bound for China generally steers due east, between the parallels of 36° and 40° south, as far as the meridian of 80° east. Then turning, first north-east and then due north, passes the Strait of Sunda, and enters the China Sea through the channel of Banca. During the prevalence of the north-east monsoon, the best passage is directly east from the Cape to Australia, a little south of the other route; then, having passed either through Bass Strait or round by Tasmania, to sail north-east to the New Hebrides, and then round to China. There are several routes **from the Cape to India.** The most direct, during the south-west monsoon, is through the Mozambique Channel; some, however, to avoid the supposed dangers of this channel, go to the east of Madagascar. During the north-east monsoon, the course is directly east to about the meridian of 80°, and then almost due north. In returning **from China and India** to Europe, the object is to get as soon as possible into the region of the south-east trade wind, for about the parallels of 15° or 18° south this wind blows with great steadiness. During the north-east monsoon, vessels from the Malabar coast, the Persian Gulf, and other countries lying to the west, sometimes take the Mozambique Channel.

The navigation of the Pacific Ocean is not so difficult as that either of the Indian Ocean or the Atlantic. **From Australia** vessels can almost sail in a straight line to Cape Horn. **From South America to China** there are two main routes: 1. From Callao, Guayaquil, or some other port, westward to the Marquesas; then south of Gilbert Islands and east of the Pelews to the Philippines. If the south-west monsoon is prevailing, the course is through the Strait of S. Bernardino; if it be during the north-east monsoon, the vessel rounds the northern extremity of the Philippines. 2. Taking advantage of the trade wind, the vessel reaches the Sandwich group, and then steers westward in 12° or 15° north latitude, where the trade wind is strong. In returning to America, vessels keep about 28° north latitude, so as to avoid the north-east trade, and have the return winds as far as California; or, if necessary, they cut across the trade wind. During the north-east monsoon, vessels sailing from China direct their course south-east until about the parallel of New Caledonia, when there is plain sailing across the ocean. The first part of this course is rather dangerous, owing to numerous islands and coral banks.

CHAPTER X.

CLIMATE. — ZONES OF TEMPERATURE. — CAUSES WHICH INFLUENCE CLIMATE.—ISOTHERMAL LINES.—GENERAL REMARKS.

Climate is a word better understood than defined; it includes not only temperature, but also everything which affects the weather; and thus the climate of any place may be warm or cold, dry or humid, equable or variable, mild or excessive. The main point, however, to be attended to in noticing climate is, of course, temperature; and this is generally given in the degrees of a *thermometer*. This very useful instrument, which has already been referred to in these chapters, consists, in its simplest form, of a glass tube of uniform bore, partially filled with mercury or quicksilver, containing a hollow bulb at one end, and sealed at the other. As mercury readily expands with heat, and contracts by cold, the column in the tube rises or falls with every change of temperature; and as the tube is carefully graduated, we are enabled to express the temperature of any place at any time, by mentioning the number of degrees to which the mercury has risen. There are two thermometers in general use—that of Fahrenheit, and the one called the *Centigrade* thermometer. In the former the temperature of boiling water is given at 212°; while the freezing point is fixed at 32°. This is the thermometer to which we shall refer in this work. In the Centigrade thermometer the boiling point is fixed at 100°; and the freezing point at 0°, or *zero*. It will thus be seen that the value of a degree is not the same in both these instruments, though the degrees of one may be reduced to those of the other.

It has been already observed (p. 46) that we obtain all our heat from the sun, and that the atmosphere is the chief means of spreading out the heat, thus received, all over the earth. From the shape of our globe it happens that all parts of the earth cannot be equally heated by the sun's rays; the equatorial parts must have a higher temperature than the parts near the poles; and the inclination of the earth's axis (p. 16), to which we owe the seasons, does not destroy this diversity of temperature, but rather increases it. Old geographers were accustomed to represent the temperature of the earth, by dividing its surface into five zones. The part between the tropics of Cancer and Capricorn was called the **Torrid zone,** because there the influence of the sun was supposed to be greatest. The districts round either pole, that is, within the Arctic and Antarctic circles, were called **Frigid zones**; because there the sun was supposed to have the least influence; and the two divisions between the frigid zones and the tropics, on the north and south sides of the equator respectively, were called **Temperate zones,** because there it was supposed that the sun was neither very hot nor very cold.

But when climate was more studied and better understood, it was found that these zones gave but a very imperfect idea of the distribution of temperature over the earth. It is found that there are so many causes which modify the temperature of places, that latitude alone is far from giving a sure index to it. The hottest place on the globe is a district lying between the 15th and 30th parallels north, and stretching from the centre of the Desert of Sahara to the shores of the Persian Gulf. In the Sahara, the thermometer in the shade frequently rises to 113°. The coldest place on the globe is in Siberia, along the middle and lower courses of the River Lena, where in January the temperature is 40° below zero. It is plain, therefore, that there are other causes affecting temperature besides position with respect to the equator, and some of these may be now briefly mentioned. In doing so, however, we shall include all those influences which affect *climate*, properly so called.

1. **Surface.**—It has been already mentioned (p. 46) that the higher we ascend into the air the colder it becomes, and that an elevation of 350 feet makes a difference in temperature of 1° Fahrenheit. Now, as this is about the same as would be felt by moving 1° nearer the pole, we can understand that in ascending some of these high mountain-chains which are within the tropics, we might, in passing from the hot plains at the base to the snow which constantly rests on the summit, pass through the same gradations in temperature as we would in travelling from the equator to the poles. Hence, Quito, situated almost upon the equator, enjoys a mild and temperate climate, since it is elevated more than 9000 feet above the sea-level. In India, again, Europeans find sanitary stations in the elevated regions of the Ghauts and Neilgherry hills; and by ascending the height of 1000 feet, they can find a temperate climate to recruit their health, which has been broken by living in the hot burning plains lying along the coast. But not only does the *elevation* of a surface influence the temperature, a great deal depends on the *character* of the surface. It is the temperature of the *atmosphere* which affects the thermometer, and the atmosphere is only partially heated by the *direct* rays of the sun; it derives most of its warmth from the heat reflected from the earth. Now, some surfaces reflect heat better than others; land radiates heat better than water; white surfaces reflect more than dark ones. This will help us to account for the great heat felt in the deserts of Africa and Arabia, and to understand how draining the land, and clearing away forests have mitigated the severity

of the climate in some districts. We may notice also how the colour of snow tends to increase the little heat there is felt in high latitudes.

2. **Presence of Large Bodies of Water.**—Water has a great capacity for heat, but does not radiate it so quickly as land. Hence water has not such a high temperature as land in summer, nor does it fall so low in winter. And those countries which, owing to a large extent of coast, are much influenced by water, partake of its equable character. Hence we may account for the mild climate of the British Islands compared with the extreme climates of countries removed from the sea. Thus, Penzance, in Cornwall, and Barnaul, at the foot of the Altai Mountains, in Siberia, are nearly upon the same parallel of latitude, and have both nearly the same temperature in summer,—that is, about 60° Fahrenheit. But while the difference between the mean temperature of summer and winter is only about 16° at Penzance, at Barnaul it is above 55°. In Canada the mean summer temperature is about 70°, while the temperature of winter varies from 20° above to 25° below zero; but even here the equalizing influence of large masses of water is felt, for in the districts round the great lakes the climate is more mild and equable than in other parts.

As evaporation is more abundant from the surface of water than from land, another consequence of the presence of masses of water is, that the climate of maritime countries is more humid than is that of countries further inland; and the moisture of the atmosphere is shown in the luxuriant verdure of such countries. For this reason Ireland claims its title of "emerald isle;" and if we turn to the other side of the globe, we shall find that New Zealand can boast of the same bright verdure and luxuriance of vegetation, owing to the same cause.

3. **Currents of the Ocean.**—Foremost among the currents which influence climate is the Gulf Stream, to which the whole of Western Europe owes the mildness of its winters. A warm current of similar character, we have seen, flows in the Pacific, and no doubt it is owing to

this current, as well as to the west winds, that British Columbia enjoys a climate similar to that of Britain itself. The open sea in Arctic regions, where we have water with a temperature of 36°, surrounded by districts where the thermometer is below zero (p. 62), is owing to an undercurrent which brings with it the heat of the tropics; and we can easily understand what an immense influence the comparatively warm waters of this open sea must have in mitigating the rigour of these frozen regions. But in other places there are cold currents. We have already noticed Humboldt's current; and its effect upon the coast of Chili and Peru is such as to cause the temperature there to be lower than on the eastern coast of South America, contrary to the general rule.

4. **Winds.**—Every one living in England must be aware of the great influence winds have upon climate. In the early days of spring the prevalence of east winds will continue the frosts of winter into the months of April and May, while, if the wind veers round to the west, the thermometer instantly rises, and the heat sometimes becomes oppressive. The reason of this has been already explained. The winds which prevail in temperate regions are generally either from the north-east or south-west; if the former, they bring the cold of high latitudes; if the latter, they convey with them the heat of the tropics: and hence, as has been already remarked, as a rule, the east coasts of continents are colder than the west coasts. But there is another reason why west winds should be warm winds; these winds, as we have seen before, are the rain winds of temperate regions, and whenever rain is deposited, a quantity of heat is given out which was before latent. Water requires a certain amount of heat to change it into vapour, and this heat becomes latent: when, however, the vapour is again condensed, the heat is given out. Thus the great amount of evaporation which is constantly taking place within the tropics tends to reduce the normal temperature of those regions; and the rains which fall in temperate and cold regions tend to raise the temperature

of those parts. We all must have remarked how close and sultry the air often feels after heavy rains: and, owing to this cause, the coast of Norway and the shores of British Columbia have a higher temperature than, from their position, we should have expected.

There are other causes, besides those we have enumerated, which affect climate, but these will be sufficient to show that the latitude of any place will be far from giving us the temperature. To show how the normal temperature of a place is changed by other causes, **Isothermal lines**, or lines of equal heat have been constructed. These lines are drawn through all places which have the same mean annual temperature; and the distribution of heat over the globe is thus at once made apparent. Thus, commencing with the tropics, we have two isotherms denoting a mean annual temperature of 80°. One commences in the Pacific, on the line, bends to the north as it approaches the continent of America, passes through Central America, and then, bending south, passes through Venezuela and Guiana, sweeps across the Atlantic, through the Guinea Coast, turns northward to the district of greatest heat, and is continued through the northern parts of Hindostan; and then, bending south through further India, again approaches the equator. The other isotherm begins in the Pacific, 15° south of the equator, rises as it approaches the shores of Ecuador and New Granada, makes a sudden bend to the south almost as far as Rio Janeiro, again turns northward, and strikes the coast of Africa a little south of the line, bends again to the south in crossing the continent, touches the northern extremity of Madagascar, crosses the Indian Ocean, and is continued through the isles of the Eastern Archipelago into the Pacific.

The isotherm of 60°, in the northern hemisphere, passes through the Mediterranean: in the southern hemisphere it crosses the continent of South America near the mouth of the La Plata, bends northward in the Atlantic, till within the tropics, then, turning south, passes through Cape Town, touches on the southern coast of Western Australia, runs through Melbourne, and almost touches the northern extremity of New Zealand. Round the southern extremity of this group of islands runs the isotherm of 50°, which, in the northern hemisphere, passes through Vancouver's Island, then, turning southward, reaches New York. In crossing the Atlantic the line follows the course of the Gulf Stream, reaches the west coast of Ireland, passes through Dublin and London, turns southward on reaching the Continent, touches at Brussels and Vienna, and is continued through the Crimea into Asia. It crosses this continent in almost a straight line, inclining a little to the south, and enters the Pacific through the strait which divides the two Japanese islands, Yesso and Niphon.

But places may have the same mean annual temperature, and yet differ very much in the character of their climate. Take London and Vienna for example: the mean winter temperature of the former is 37°, its mean summer temperature 64°; on the other hand, Vienna has a mean winter temperature of 27°, while in summer the mean temperature is 70°. It is very important that the extremes of heat and cold should be noticed; for while some plants, like the myrtle, cannot endure severe winters, others, like the vine, may live through a severe winter, but require a certain amount of summer heat to bring their fruit to perfection. Hence other lines, showing the mean summer and the mean winter temperatures of places, have been constructed; the former are called **Isotheres**, or isotheral curves; the latter, **Isocheimenes**, or isocheimal curves. As water does not part so rapidly with its heat as land does, it preserves a more equable temperature throughout the year, and hence countries situated near the sea have a more moist and equable climate than those further inland. According to the amount of variation in their annual temperatures, climates have been divided into three kinds:—

1. *Insular and tropical climate*, where the variation does not reach 30°.
2. *Continental climate*, with a variation of from 30° to 60°.
3. *Excessive climate*, with a variation of 60° or more.

Within the tropics the heat of the sun is so great that modifying causes have very little effect upon the temperature, and hence the difference in temperature between the hottest and coldest months is not so great as in higher latitudes; thus, in British Guiana, the difference between the hottest and coldest months is only 2° 2′ Fahrenheit.

Before concluding this chapter, it may be remarked that, upon the whole, the climate of the New World is warmer and more moist than that of the Old World; and that the northern hemisphere has a mean annual temperature about 4° above that of the southern hemisphere. This latter statement may require some explanation. Although the sun is actually three million miles nearer the earth in winter than in summer, yet the amount of heat received by the earth at both these periods is the same (p. 19). Therefore, as far as this cause is concerned, the southern hemisphere should have as high temperature as the northern, but no higher. Since, however, there is more water to the south of the equator than to the north of it (p. 39), and as water is not such a good radiator of heat as land is, we should expect that the southern summers would not be so hot as the northern ones, but that the winters would be milder. Such is the case to some extent, and hence it is found that the mean temperature of the whole globe goes on increasing from January to July. But the climate of the southern hemisphere is still further cooled by the prevalence of cold currents in the Southern Ocean (p. 59), and by the free passage given to icebergs coming from the Antarctic Ocean: when to this is added the fact that more rain falls in the northern hemisphere than in the southern, while there is less evaporation, and when we recollect that the temperature of a place is lowered by evaporation, but raised by precipitation (p. 71), we shall have no difficulty in understanding that the mean temperature of the northern hemisphere is a little above that of the southern hemisphere.

CHAPTER XI.

VEGETABLE ZONES. — DISTRIBUTION OF PLANTS AND ANIMALS.—ORIGIN OF EXISTING VEGETATION.—ACCLIMATISATION.—PLANTS OF COMMERCIAL IMPORTANCE.

Plants depend for their very existence upon heat and moisture, and hence their distribution depends on the variety of climates. And just as the globe has been divided into five zones of temperature (p. 68), so there are certain zones of vegetation, which, though not rigorously correct in all cases, yet are convenient for reference, and give a good general idea of the distribution of plants. These are as follow:—

1. The equatorial zone of Palms and Bananas, extending on both sides of the thermal equator to about 15°.
2. The tropical zone of tree Ferns and Figs, from 15° to the tropics.
3. The sub-tropical zone of Myrtles and Laurels, from the tropics to latitude 34°.
4. The warm temperate zone of Evergreen trees from latitude 34° to 45°.
5. The cold temperate zone of European trees from latitude 45° to 58°.
6. The sub-arctic zone of Pines, from latitude 58° to the polar circle.
7. The arctic zone of Rhododendrons, from the polar circle to latitude 72°.
8. The polar zone of Alpine plants, beyond latitude 72°.

As, in passing from the base of a mountain within the tropics to the regions of eternal snow, we pass through the various climates which exist on the surface between the equator and the poles, so we pass through the different vegetable zones. The laws, however, which relate both to the vertical and horizontal distribution of vegetables, are subject to certain local modifications: some plants seem limited to certain districts, owing to causes with which we are not well acquainted. Hence the whole globe has been divided into twenty-five **Phyto-geographic regions**, or botanical centres; each of which is distinguished by the peculiar features of its vegetation. Thus, the shores of the Mediterranean form the region of the *Labiatæ and Caryophyllæ* (to which the pink, catchfly, and sandwort belong). This region is distinguished by the number of its aromatic plants and fragrant rock-roses: there is an abundance of evergreen trees, but an absence of verdant turf. In South America we have the region of *Cinchonæ* (medicinal barks). This region is confined to the range of the Andes between the parallels of 5° north and 20° south latitude, at an elevation of from 5500 to 9600 feet above the level of the sea.

In South Africa, between the tropic of Capricorn and the Cape, we have the region of *Mesembryanthema, or Fig Marigolds and Stapelias*. This district is marked by the presence of plants with thick fleshy leaves, but bright and beautiful flowers. Here are found aloes, geraniums, irises, but, above all, heaths; of these last there are about 400 species, all exceedingly beautiful. Turning now to Australia, we find the southern half of it marked as the region of the *Epacrides and Eucalypti*. Here the trees are all evergreen with grass-like and stunted foliage: here flourish the myrtle, the acacia, and gum-tree, with arborescent ferns and nettles of gigantic size. New Zealand forms another region, distinguished by its graceful ferns and valuable pines: the flax plant is also very abundant.

Animals depend in a great measure upon plants for food, and, like plants, are subject to certain conditions of climate. Hence, both are subjected to the same laws, to some extent, in their distribution over the surface of the globe. The development of animal and vegetable life increases in energy and variety from the poles to the equator: this law, however, is reversed with regard to marine animals, for they increase, at least those of higher organization, from the equator to the poles. It has been noticed also, that animal life decreases as we recede from the coasts to the interior of continents: for, as the climate is here less humid, vegetation is less abundant, and, of course, is less able to support the numerous tribes of animals which inhabit the maritime districts. But it may here be remarked, that although in such cases animal life is less abundant, yet in the arid plains of the interior the *individual* forms of life are better developed, and of greater strength and beauty; as, for example, the lion, which inhabits the interior of Africa. Animals, also, are subject to the same law as plants, with regard to vertical distribution. Thus, it has been said that the Himalayas, which from their base to their summits exhibit a temperature varying from the heat of the equator to the cold of the poles, also present a succession of species similar to what a traveller would meet with in going from India to Kamtschatka.

It has been found that, while a moist and warm climate is most suitable to vegetable life, a dry and hot climate brings animal life to greatest perfection. Hence, if we compare the organic productions of the Old and New Worlds, we shall find that while the latter is distinguished for the luxuriance and leafiness of its vegetation, the former is remarkable for the beauty and strength of its animals. Thus, South America is the region of the palm trees, which are distinguished by their height and the abundance of their foliage; while Africa, with its stunted foliage, can support the rhinoceros, hippopotamus, and the giraffe—the last of which has not even a representative in America. There are two classes of animals, however, which, as they depend immediately for their existence upon vegetation and warmth, come to great perfection in the New World—insects and reptiles. Nothing is so beautiful as the bright sparkling insects of South America; and nowhere are lizards, crocodiles, and serpents larger and more numerous. On the other hand, it is in the Old World that spices—the nutmeg, the clove, and ginger—are brought to greatest perfection; for these, as well as aromatic fruits in general, seem to require a dry, hot climate in order to have their juices and perfume perfectly elaborated.

The characteristic animals of any region, embracing all the species, terrestrial and aquatic, are called a **Fauna**, just as the plants of any district form its **Flora**; and as the whole globe has been mapped out into twenty-five botanical centres, so the Fauna has been divided into five zoological kingdoms, each of which has certain subdivisions.

1. The **European** kingdom is divided into the north, middle, and southern provinces. The southern limit of the northern province almost coincides with the 60th parallel; while the great range of mountains extending from the Atlantic to the Black Sea, divides the middle from the southern province. Europe is especially noted for its birds, in the number of the species of which it exceeds any part of the globe with the exception of tropical America.

2. The **Asiatic** kingdom. This is also divided into three provinces, the central one being bounded on the north by the Altai Mountains, and on the south by the Himalayas and Hindoo Koosh. This kingdom, but especially the tropical province, is distinguished by the number of its Carnivora. This order of animals increases in the number of its species from the poles to the equator; and if we compare the tropical provinces of America, Africa, and Asia, we find the numbers of species found in them to be 109, 130, and 166 respectively. The Asiatic kingdom includes a part of the Indian Archipelago; and so well is the boundary marked, that, while in the Moluccas and at Timor there is a great abundance of Carnivora, on New Guinea, which is separated only by a narrow arm of the sea, these animals are almost, if not altogether, wanting.

3. The **Oceanic** kingdom. This kingdom, which only forms one province, includes Australia, Van Diemen's Land, the islands stretching from New Guinea to New Zealand, and the small groups of Polynesia. This pro-

vince or kingdom is distinguished by the presence of Marsupial, or pouched animals, and by the absence of the three orders of quadrumana (monkeys), pachydermata (thick-skinned animals, like the elephant, rhinoceros, horse), and ruminating animals, such as the ox, deer, or sheep. The south-eastern districts of Australia contain the greatest number of Marsupials; while in Europe, Asia, and Africa, these animals in their native state are unknown.

4. The **African** kingdom includes Africa, with the peninsula of Arabia, and the islands of Madagascar, Bourbon, and Mauritius. This kingdom is marked by the abundance of its Pachyderms. More species of this order occur in Africa than in any other part of the globe, and a species of elephant and the double-horned rhinoceros are peculiar to it.

5. The **American** kingdom is divided into four provinces, namely, those of Arctic, Northern, Tropical, and Southern America. The arctic province includes British and Russian America; the northern includes the United States; the tropical province embraces Central America, the West Indies, and South America as far as the parallel of 40° south latitude; the remaining portion of the continent forms the fourth province. It has been already remarked that the New World is not so rich in large animals, neither as regards species nor individuals, as is the Old World; but some particular orders and families are abundantly represented. Thus, tropical America is exceedingly rich in birds, reptiles, monkeys, and insects; and the order of Edentata, or toothless animals, chiefly inhabits the countries of South America, where the number of species is almost three times as many as are found in Asia, Africa, and Australia put together.

Origin of Existing Vegetation.—We have remarked that some plants appear to be limited to certain regions owing to causes with which we are not well acquainted; perhaps some light may be thrown upon this subject by a reference to geology. It has been already stated (p. 30), that in the older systems of stratified rocks, vegetation was either wholly wanting, or only appeared in its lowest forms; but that gradually as the earth assumed its present condition, both as regards the distribution of land, and also climate, the different orders of plants increased in number and perfection. Thus, during the period when the carboniferous strata were being formed, it would appear that two-thirds of the abundant vegetation which then clothed our globe was composed of arborescent ferns; while the greater portion of the remainder consisted of club-mosses and equisitaceæ, all families belonging to the inferior order of cryptogamous plants. Another characteristic of the flora of that period was its uniformity; the fossil plants found in the coal-fields of Europe are identical with those found in the coal-beds of the tropics. It may be interesting, then, to consider how this lower vegetation has gradually been displaced by the more perfect flora which now exists. It would be out of place here to give the various theories which have been advanced on this subject, but one or two conclusions, which are generally admitted, may be mentioned:—1. It is supposed that originally each species of plant had a particular centre from which it gradually spread all around. The fact of some plants appearing in widely different localities, might, at first thought, seem to overthrow this opinion; but when we consider the extensive areas over which similar plants seem to have spread at certain geological epochs, and then remember the great changes which we know to have taken place since—the submergence and emergence of land, and the changes in its distribution, if to this we add the agencies still at work in spreading seed—birds, currents of the ocean, winds—we shall have little difficulty in believing that all plants of the same species, however wide apart they now may be, are sprung from one single species, and one centre. 2. The species of plants which first appeared on our globe were not only of a low type, but also comparatively few in number, and many of these gradually died out owing to climatic changes; while other species seem to have been introduced, suited to the new order of things. 3. It is not supposed that any new species has appeared since the creation of man, though several would appear to have become extinct. In this way, perhaps, we may account for "botanic centres," by supposing that plants which come to the greatest perfection in these regions, first appeared in those districts. Thus, South Africa may perhaps be the native habitat of the heath; South America, of the cinchona; China, of the tea-plant.

What has been said on the origin of existing vegetation will apply in a great measure to the animal kingdom. There is the same progression from lower to higher types during geological ages; the same uniformity in the earlier, and variety in the later systems. It is not until we come to the lower tertiaries that we have any evidence of a geographical distribution of animals; and at the present day we have zoological kingdoms just as we have phytogeographic regions. We may thus account for the perfection which the tiger attains in India, the elephant in Africa, the llama in South America, and the kangaroo in Australia, either by supposing that these animals have died, or are dying out in other regions, or that those particular regions are the native habitat of these particular animals.

Acclimatisation of Plants and Animals.—Previous to the creation of man, changes in the distribution of plants and animals would depend on natural causes; after man's appearance, however, though these causes would be still at work, still greater changes would be brought about by his agency. Plants and animals, useful to him, would be brought from various parts, and carefully reared in places more convenient for him, and raised to conditions of greater perfection. Thus, he early became acquainted with the various kinds of grain useful as food; and the horse, ox, sheep, and dog were reduced to a domestic state. On the discovery of America, it was found that that continent was almost destitute of useful animals, and accordingly the domestic animals of Europe were introduced along with the sugar-cane, the coffee and cotton plants, the spices, and the cereal grains. In return, America gave to the Old World the potato, the cocoa, the vanilla, the quinquina, and the tobacco-plant. More recently, the cinchona has been transplanted to the uplands of India, and the llama and alpaca have been introduced into the continent of Australia. Australia, indeed, owes as much as America itself to the plants and animals of other quarters of the globe; salmon have been introduced into its rivers, song-birds into its woods, and sheep into its extensive pastures. Nor should we forget, in this brief notice of the acclimatisation of plants and animals, the introduction of the *eland* into this country. This noble antelope is a native of South Africa; it stands fully six feet high at the shoulder, and its flesh resembles beef in colour, grain, and flavour. It will readily breed in England, and several are now found in the parks of the nobility.

Some plants are of so much commercial importance, that a separate and more detailed account of them would seem to be required.

Tea.—The tea-plant is an evergreen shrub, growing to the height of five or six feet. It is indigenous to China, Japan, and Upper Assam, but is cultivated also at Java, and to some extent in Hindostan and Brazil. There are two species, but both green and black tea may be made from the leaves of either species, collected at different periods of the year. The tea-plant is cultivated in almost every province in China, but most comes from the provinces of Fokien and Kiang-nan, the former furnishing black tea, and the latter, green. Paraguay tea, is a species of holly which grows in the forest regions of Paraguay, and from it is made the beverage *maté*, so celebrated in the Spanish colonies of South America.

Coffee.—The coffee-tree is a native of the Ethiopian highlands of Africa, whence it was introduced into Arabia in the fifteenth century. It has been introduced into both the East and West Indies, and is cultivated to a large extent in Brazil, British India, and in the island of Ceylon.

Sugar.—The sugar-cane will grow anywhere within the tropics, and beyond these limits it may be cultivated with advantage in any place where the mean temperature of the year is not less than 64°. The most important districts where it is grown are the West Indies, Guiana, Brazil; the Mauritius, Hindostan, the Philippine Islands, and Java.

Cotton.—This plant belongs to the Mallow tribe. It is a shrub, varying in height, with dark broad leaves and large yellow flowers. The fruit is a pod or capsule, which contains the seeds embedded in a white or yellowish woolly substance which forms the raw cotton. There are several species of this plant, but the best is that called "sea-island cotton," which comes from the low sandy islands lying along the coast between Charleston and Savannah in North America. Cotton will grow in almost all the countries within the torrid zone; but the greater portion at present produced comes from the United States of America. It grows also in China and India, and has been introduced into parts of Africa and Australia.

Flax and Hemp.—Flax is produced from linseed, and is a plant with a delicate stem, long leaves, and blue flowers. It is grown in the north of Ireland, and in Russia, Prussia, Holland, Belgium, and parts of France. The fibre worked up into the linen yarn comes from the stalks. The *Hemp* plant is something like a large nettle, and grows to the height of five or six feet or more. It is a summer crop in several European countries, and a winter crop in Egypt and India. Lincolnshire and Suffolk are the only counties of England in which it is cultivated.

CHAPTER XII.

THE DISTRIBUTION OF MAN.—GREAT VARIETIES OF THE HUMAN FAMILY.—SUBDIVISIONS OF THE CAUCASIAN TYPE.—CONCLUSION.

Man, by his superior physical organization, as well as by his mental endowments, is placed at the head of all other animals. Although he is, to some extent, subject to the influences of climate, yet he differs from inferior animals by being able to live in all localities, under all climates, and at all altitudes to which organic life extends. Thus, while the different provinces and kingdoms among animals, and the different botanical centres among plants, would lead us to believe that the various *Flora* and *Fauna* have been brought into existence in those regions where they flourish best, man, as he is confined to no particular locality, would seem to have had but one origin, and to have sprung but from one centre. And if, applying the same rule that is made use of in respect to other organized beings, we suppose *that* to be the cradle of mankind where man appears in the greatest perfection of form, we should inevitably be led to fix upon the regions of Armenia and the Caucasus as the centre whence man has spread, since it is in those regions that we find the purest types of manly and feminine beauty.

The deductions of reason would thus lead us to the same conclusions as the teaching of Holy Writ; and we may, therefore, have no hesitation in asserting that mankind, although now spread over every quarter of the globe, and exhibiting great varieties of colour and feature, yet sprang originally from one centre and from one pair. In the infancy of the human race, no doubt, external causes had a greater influence upon the physical constitution of man than they now have. Be that as it may, since the dawn of history there have always been certain varieties in the human family, differing from each other, not only in colour and feature, but also in intellectual character. These varieties have by some been divided into five classes, but it is more usual to speak of three great types—the Caucasian, Mongolian, and Ethiopian; while two other classes, the Malay and the American, may be looked upon as sub-varieties, which have arisen out of a combination of the other three. And here we would remark, once for all, that both in this and the preceding chapter we are indebted for our facts mainly to *Johnston's Physical Atlas.*

Caucasian Type.—This race is distinguished by a well-proportioned figure: the length of the extended arms is equal to the whole height of the body. The head is round, the face oval, the eyes well set, the nose narrow, and sometimes arched slightly. The mouth is small, the hair abundant on the head and chin, but thin on other parts of the body. The skin is generally fair and ruddy, or of various shades of brown. The hair varies in colour from yellow to black; the eyes, from blue to black. This race possesses great intellectual ability, firm perseverance, and great muscular strength. The type is divided into two great branches—the *Indo-European*, which includes the Georgians, Persians, and Hindoos, with other nations of Asia, and the greater portion of the inhabitants of Europe; and the *Semetic*, or *Syro-Arabian*, including the Syrians, Arabs, and Modern Egyptians.

Mongolian Type.—In this type the head is heavy, though not large, the cheek-bones are prominent, the nose flat. The eyes are set wide apart, and elevated at the outer corners. The skin is of an olive hue, the hair coarse and lank, the beard scanty, and the ankles weak. This race possesses less activity and endurance than the Caucasian; and the intellect, being only moderately developed, exercises itself rather with details than with general principles: it, however, shows great shrewdness and great imitative power. This branch of the human family, of which the Chinese may be regarded as the type, is deficient in imagination, but skilful in domestic arts. In moral character it is crafty and insincere, obstinate and jealous. The Mongolian type is spread over the north and east of Asia, and ranges from 75° north latitude to 50° south. The *Esquimaux* of North America also belong to this type.

Ethiopian or Negro Type.—This type is characterized by a retreating forehead, prominent and wide mouth, thick lips, flat nose, and woolly hair: the eyes and skin are both black. The back part of the head is strongly developed, showing the preponderance of the animal over the intellectual nature. The race is capable of enduring great bodily labour and fatigue, and in disposition is patient, affectionate, honest, and contented. The intellect is quick in perception, but without depth. The Ethiopian type is found in its purity in Central and Western Africa; the *Papuans*, who inhabit New Guinea and the adjacent islands, are a subdivision of it.

The Malay Race.—This race seems to have sprung from a mixture of the Mongolian and Caucasian types. The forehead is low, the face broad and flat, and the colour of the skin varies from a clear brown to a dark olive. The limbs are not powerfully formed, but they are capable of great activity. The moral character of this race is treacherous, ferocious, and implacable. The Malay race is found in the Malay Peninsula, in Java, Sumatra, Borneo, and Madagascar; and the aborigines of Australia, with their gaunt bodies, lean limbs, and crooked backs, are another variety of it.

The American Race.—This race embraces the aborigines of North and South America, and, like the Malay race, seems to be a variety of the Mongolian type. The cheek bones are high, the forehead rather low, the nose prominent, and the mouth large. The body is generally well proportioned, the skin of a red or copper colour, the eyes black, and the hair black and scanty. The habits of the American race are active and vigilant, yet incapable of long endurance; in disposition it is daring and cruel, but at the same time generous and hospitable. The

American Indian is of a cold and melancholy temperament, and shows an extraordinary insensibility to pain.

If we estimate the whole number of the human family at nine hundred millions, we may assign three hundred and fifty millions to the Caucasian race; four hundred and twenty to the Mongolian race, including the Indians of America; one hundred millions to the Ethiopian race; and to the Malay race, thirty millions.

Turning now again to the Caucasian type, to which the greater portion of the inhabitants of the British Empire belongs, and with which we are, therefore, most interested, we find, as was before remarked, that it is divided into two branches—the Indo-European and the Syro-Arabian. If we now confine our attention to that portion of the first branch which inhabits Europe, we find that it is again subdivided into three varieties, differing from each other in physical, intellectual, and moral characteristics. These varieties are the Celtic, the Teutonic, and the Slavonic.

Celtic Variety.—In this variety the skin is dark and sallow, the eyes brown or black, and the hair also black. Among intellectual and moral qualities it is distinguished for quickness of perception, power of concentration, love of equality, society, amusement, and glory; and there is always a tendency to superstition. Populations belonging to this variety are often noted for fine blandishing manners and great external politeness, which is unaccompanied by inward sympathy. They generally make bad seamen, and do not succeed as colonists.

Teutonic Variety.—The characteristics of this variety are great strength of muscle and height of stature; the skin is generally fair, the hair red or yellowish, the eyes blue, the cheeks ruddy, the forehead high and broad:—

> "Deep-blooming, strong, and yellow-haired,
> The blue-eyed Saxon came."—*Thomson.*

In mental and moral character this variety is marked by slowness but accuracy of conception: the Teuton is not witty like the Celt, and is wanting in concentration; but he is deep and acute. He is fond of independence and self-government, provident, cautious, reserved, haughty; but hospitable and forgiving. The Teutonic variety make skilful seamen, possess great musical talents, are cleanly, and fond of spirituous liquors. It may be remarked, that owing to superior intellectual ability, the Teutonic variety has everywhere conquered the other races and varieties with which it has come in contact.

Slavonic Variety.—This variety is marked by a sallow complexion, in shade between the Celtic and Teutonic: the eyes are generally grey or brown, the hair coarse and lank, the cheek-bones prominent, the forehead low. The Slavonian is generally short and thickset in stature, but possesses great muscular strength, and is of a hardy constitution. He is distinguished for great mechanical skill and power of imitation, and is fond of music, songs, and poetry. When under subjection he is cunning, deceitful, and revengeful; but when free, frank and open. He is tenacious of old manners and prejudices, and is remarkable for a love of country and a want of cleanliness.

The Celtic variety prevails generally in Central and Southern Europe, in France, Spain, Portugal, Italy, Greece, parts of Switzerland and Germany, and in Belgium; and in all these countries, with the exception of Greece, the Roman-catholic religion prevails. The Teutonic variety is found in Northern Germany, Prussia, Holland, Denmark, Norway, and Sweden; and these countries are all Protestant. The inhabitants of Russia, the eastern part of Austria, and the greater portion of the people of Turkey, belong to the Slavonic variety, and here the prevailing religion is that of the Greek Church. In Great Britain, the Teutonic race prevails, with an admixture of Celtic blood; in Ireland, the Celtic element preponderates. The original inhabitants of the British Islands were Celtic, though with a greater admixture of the Teutonic variety than is commonly supposed: the Picts and Scots both seem to have had a Teutonic origin. When the Saxons invaded Britain in the fifth century, the Celtic inhabitants were driven back into the mountainous parts—into the Highlands of Scotland, Wales, and Cornwall. Next came the Northmen and Danes, who established themselves in the islands round Scotland, and on the north-east coasts of England, Scotland, and Ireland. Lastly, there was the invasion of the Normans, who, after the battle of Hastings (1066), became for awhile the predominant race in these islands. We cannot conclude this part of our subject better than in words taken from a work to which we are already largely indebted:—

"It is evident that the English people are not an entirely or purely Teutonic race, but that the admixture of Celtic blood has been gradually swallowed up, not only in the midland counties of England, but even in the more western counties,—Wales, of course, especially the southern part of it, excepted,—so that we may fairly assert, that whilst the inhabitants of the eastern and northern counties are (with very slight local exceptions, perhaps) entirely Teutonic, the mass of the English people, and of the Lowlands and the eastern coasts of Scotland, is a cross-breed, with four-fifths, at least, of purely Teutonic blood. It has taken hundreds of years ere this intelligent, active, persevering, industrious race of Britain has come forth out of this process of mixture which was going on during the middle ages, and that fine race of human beings has been formed for which Britain is so justly famed. Every one who has seen the principal countries of Europe will unhesitatingly admit that no finer men can be found than in the middle and higher classes of Britain; whilst female beauty, at least in England, is found inherent in individuals of all classes of society."—[*Johnston: Physical Atlas.*]

PRINTED BY OLIVER AND BOYD, EDINBURGH.

EXHIBITION MEDAL LIST.

EDUCATIONAL WORKS

PUBLISHED BY

OLIVER AND BOYD, EDINBURGH;

SIMPKIN, MARSHALL, AND CO., LONDON.

This List is confined to the Works exhibited by Oliver and Boyd, for the merit of which a Medal has been awarded by Her Majesty's Commissioners of the International Exhibition of 1862.

ENGLISH READING, GRAMMAR, ETC.

	s.	*d.*
Connon's System of English Grammar	2	6
Demaus' Selections from Paradise Lost, with Notes	1	6
.... Analysis of Sentences ... *Reduced to*	0	3
Ewing's Principles of Elocution, *improved by Calvert*	3	6
Fulton's Edition of Johnson's Dictionary	1	6
Lennie's Child's A, B, C, Part I. 1½d.—Part II	0	3
.... Child's Ladder	0	10
.... Principles of English Grammar [The *Key*, 3s. 6d.]	1	6
M'Culloch's First Reading-Book	0	1½
.... Second Reading-Book	0	3
.... Third Reading-Book	0	10
.... Fourth Reading-Book & Synopsis of Spelling	1	6
.... Series of Lessons in Prose and Verse	2	0
.... Course of Reading in Science and Literature	3	0
.... Manual of English Grammar	1	6
.... Prefixes and Affixes of the English Language	0	2
Milden's Initiatory English Grammar	1	0
Reid's Rudiments of English Grammar	0	6
.... Rudiments of English Composition [The *Key*, 3s. 6d.]	2	0
.... Pronouncing Dictionary of the English Language	6	6
Sessional School Etymological Guide	2	6
.... Old Testament Biography	0	6
.... New Testament Biography	0	6
Spalding's (Professor) History of English Literature	3	6
White's System of English Grammar	1	6

MATHEMATICS, NATURAL PHILOSOPHY, ETC.

Ingram's Mathematics, by Trotter [The *Key*, 3s. 6d.], *reduced to*	4	6
.... Mensuration, by Trotter	2	0
Ingram & Trotter's Euclid's Plane Geometry and Trigonometry	1	6
Lees' Catechism of Natural Philosophy, Parts I. & II., each	0	9
Nicol's Introductory Book of the Sciences	1	6

Oliver and Boyd's Exhibition Medal List.

GEOGRAPHY AND ASTRONOMY.

	s.	d.
Edinburgh Academy Modern Geography, *improved*	2	6
Ewing's Geography, with Astronomy and Physical Geography	4	6
...... with 14 Maps	6	0
Murphy's Bible Atlas, 24 Maps, coloured, with Hist. Descriptions	1	6
Reid's Rudiments of Modern Geography (Map), 1s.; with 5 Maps	1	3
Abridgment of Ditto	0	6
.... Outlines of Sacred Geography, with Map of Palestine	0	6
.... Introductory Atlas of Mod. Geography, 10 Maps, *revised*	2	6
.... School Atlas of Modern Geography, 16 Maps, *revised*	5	0
Reid's (Hugo) Elements of Astronomy	3	0
...... Physical Geography, with Astronomy (Phys. Chart)	1	0
Stewart's Modern Geography, with Physical Geog. & Astronomy	3	6
White's Abstract of General Geography, 1s.; with 4 Maps	1	3
.... System of Modern Geography, 2s. 6d.; with 4 Maps	2	9

HISTORY.

	s.	d.
Simpson's History of Scotland, with Map	3	6
.... Goldsmith's History of England, with Map	3	6
.... Goldsmith's Rome, with Map	3	6
.... Goldsmith's Greece, with Map	3	6
Tytler's Elements of General History, *continued* to 1862, with 2 Maps, Frontispiece, etc.	3	6
Watts' Scripture History, with Notice by Dr Tweedie	2	0
White's History of England for Junior Classes	1	6
.... History of Scotland for Junior Classes	1	6
.... History of Scotland for Senior Classes	3	6
.... History of Great Britain and Ireland, *continued* to 1862, with Map, *reduced to*	3	0
.... History of France, with Map	3	6
.... Sacred History	1	6
.... Outlines of the History of Rome	1	6
.... Outlines of Universal History	2	0
.... Elements of Universal History, *continued to* 1862, 7s.; *or in* 3 *Parts*, each	2	6

WRITING, ARITHMETIC, AND BOOK-KEEPING.

	s.	d.
Hutton's Arithmetic & Book-Keeping, by S. & D. Entry, by Trotter	2	6
.... Book-keeping, by S. & D. Entry, by Trotter, separately	2	0
Two Ruled Writing Books for Ditto: Single Entry	1	6
...... Double Entry	1	6
Ingram's Principles of Arithmetic, *Improved Edition* [*Key*, 2s. 6d.]	1	0
Melrose's Arithmetic, by Ingram and Trotter [The *Key*, 3s. 6d.]	1	6
Scott's Writing Copy Books, with Engraved Headings, in a progressive Series of 20 numbers: Post Paper each	0	4
.... Copy Lines, 30 Sorts each	0	4

REMODELLED AND GREATLY ENLARGED,

WITH EXERCISES ON

THE PROPOSED DECIMAL COINAGE.

INGRAM'S PRINCIPLES OF ARITHMETIC and their Application to Business explained in a Popular Manner, and clearly Illustrated by Simple Rules and Numerous Examples. For the Use of Schools. 42d Edition. By ALEXANDER TROTTER, of the Scottish Institute. 18mo, 150 pages, 1s. bound.

The Elementary Rules are explained in concise and intelligent language, adapted to the capacity of youth; and the various exercises are so arranged—commencing with the most simple, and increasing in difficulty by imperceptible degrees—that no obstruction to the progress of the pupil can possibly be apprehended. *Each rule is followed by an example wrought out at length*, and is illustrated by a great variety of practical questions applicable to business.

The present edition has been remodelled and subjected to a careful revision,—the exercises in the Simple and Compound Rules have been rearranged and extended, Fractional Arithmetic has been more fully treated, the exercises in the higher branches of the science have been greatly increased, and a large collection of Miscellaneous Questions has been given: the introduction of a Decimal Coinage into this country having been for some time under the consideration of Government, several pages have been devoted to that system which is most likely to be preferred. A larger and more distinct type has been adopted, without increasing the price of the work, and the utmost care has been taken to secure perfect accuracy.

KEY to the IMPROVED EDITION, 2s. 6d

Edinburgh: OLIVER AND BOYD.
London: SIMPKIN, MARSHALL, AND CO.

MR GORDON'S BOOKS, now issued by OLIVER & BOYD.

How to Train Young Eyes and Ears.

Being a MANUAL of OBJECT LESSONS for PARENTS and TEACHERS. By MARY ANNE ROSS, Mistress of the Church of Scotland Normal Infant School, Edinburgh. 1s. 6d.

Household Economy.

A MANUAL intended for Female Training Colleges, and the Senior Classes of Girls' Schools. By MARGARET MARIA GORDON (Miss Brewster), Author of "Work, or Plenty to do and how to do it," etc. Eighth Thousand. 2s.

Greek Syntax.

With a Rationale of the Constructions, by JAMES CLYDE, LL.D., one of the Classical Masters of the Edinburgh Academy. With Prefatory Notice by JOHN S. BLACKIE, Professor of Greek in the University of Edinburgh. Second Edition. 4s.

Greek Grammar for the Use of Colleges and Schools.

By Professor GEDDES, University of Aberdeen. Fifth Edition. 4s.

Latin Grammar for Elementary Classes.

By D'ARCY W. THOMPSON, M.A. Cantab., one of the Classical Masters of the Edinburgh Academy. Second Edition. 2s.

The Functions of Si and Qui.

With special reference to German Theories. By GAVIN HAMILTON, Elgin Academy. 8vo. 6s.

Theoretical and Practical Italian Grammar.

With numerous Exercises and Examples, illustrative of every rule, and a selection of Phrases and Dialogues. By E. LEMMI, LL.D., Italian Tutor to H. R. H. The Prince of Wales. Sixth Edition. 5s.

Grammar of the French Language.

By AUGUSTE BELJAME, B.L. Paris. Third Edition. 2s.; or with Exercises, 3s. 6d. Exercises separately, 2s.

The Port-Royal Logic.

Translated from the French, with Introduction, Notes, and Appendix. By THOMAS SPENCER BAYNES, B.A. Fifth Edition. 4s.

School Register.

PUPIL'S DAILY REGISTER OF MARKS. Space for 52 *Weeks*. 2d. Constructed so as to furnish information required by Government.

School Register of Attendance, Absence, and Fees.

Arranged by MORRIS F. MYRON, Parochial Schoolmaster of Clyne. Intended for use in Boys', Girls', or Mixed Schools. 1s. Each folio will serve 50 Pupils for a Quarter.

**** A specimen copy of any Book will be sent* POST-FREE *on receipt of the retail price in postage stamps.*

GORDON'S SCHOOL AND HOME SERIES.

NOW PUBLISHED BY OLIVER AND BOYD.

THE object of the SCHOOL AND HOME SERIES OF READING BOOKS is at once to provide CHEAP EDITIONS OF JUVENILE CLASSICS FOR HOME READING, and to place interesting and attractive Books within the reach of SCHOOLS AND SCHOOL LIBRARIES.

From the Report of the Jurors of the International Exhibition.

"The Jury have been interested in observing that a somewhat bold experiment of the Messrs GORDON of Edinburgh has been tried with great promise of success. These Publishers have reprinted, under the name of the 'School and Home Series,' some of the most Popular Tales for Children, including, besides *Robinson Crusoe* and *Lamb's Tales from Shakespeare*, the most attractive stories of Fairies and Giants. They have not attempted by annotation or abridgment to make their books look like treatises, but have been content to rely on the fascination of the stories themselves, as the best means of overcoming the mechanical difficulty of reading."

The Child's Story Book.

Illustrated. Cloth, 1s.; or, extra gilt, for Prizes, 1s. 6d. Also, in 6 parts, 2d. each, viz.:—

1. Jack and the Bean-Stalk. Cinderella; or, The Little Glass Slipper. Little Red Riding-Hood. The Babes in the Wood.
2. Tom Thumb. Little Jack Horner. Puss in Boots. Jack and Jill. Old Mother Hubbard. The Old Woman who Lived in a Shoe. Whittington and His Cat. The Old Woman Tossed up in a Basket. Little Bo-Peep.
3. Jack the Giant-Killer. Ding Dong Bell. Beauty and the Beast. Four-and-Twenty Tailors. Henny-Penny. A Man of Words and not of Deeds. The Three Bears. I had a Little Husband. Simple Simon. Sing a Song of Sixpence.
4. Ali Baba and the Forty Thieves. Old Mother Goose. The Sleeping Beauty in the Wood. The Wolf and the Goats. One, two; button my shoe. Tom, Tom, the Piper's Son. The Wolf and the Fox. The Fox and the Farmer.
5. Aladdin or the Wonderful Lamp.
6. Sindbad the Sailor. The Crooked Man. Ride a Cockhorse. Tom Thumb's Alphabet. The House that Jack Built. The Death and Burial of Poor Cock Robin. I saw a Ship a-Sailing.

Robinson Crusoe. UNABRIDGED. *With Illustrations.* 8d.

The Robins. By MRS TRIMMER. *With Illustrations.* 6d.

Lame Jervas. By MISS EDGEWORTH. *With Illustrations.* 4d.

To-Morrow. By MISS EDGEWORTH. *With Illustrations.* 4d.

Lamb's Tales from Shakespeare.

Illustrated. 1s.; or in Four Parts, 3d. each, viz.:—

1. The Tempest. Taming of the Shrew. Romeo and Juliet. Twelfth Night.
2. A Midsummer Night's Drea
A Winter's Tale. King L
Hamlet.
3. Macbeth. Much Ado about Nothing. As You Like it. All's Well that Ends Well.
4. [illegible] Two Gentle-
of Errors.

Gulliver's Travels. 8d.; o

1. Travels in Lilliput.